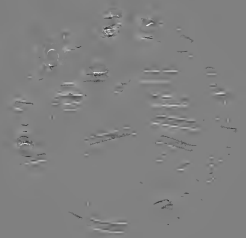


CONFIDENTIAL
RESEARCH REQUEST
REF-000

IMPROVED METHODS FOR
STATE-WIDE VEHICLE
COUNTING

Shih-wai Hong, Chen



Digitized by the Internet Archive
in 2011 with funding from
LYRASIS members and Sloan Foundation; Indiana Department of Transportation

Report

IMPROVED METHODS FOR STATE-WIDE VEHICLE COUNTING

TO: H. L. Michael, Director
Joint Highway Research Project

May 13, 1981

FROM: G. T. Satterly, Jr., Research Engineer
Joint Highway Research Project

Project: C-36-54AA

File: 3-3-27

The attached report, "Improved Methods for State Wide Vehicle Counting," is submitted in fulfillment of the objectives of the research. It has been authored by Mrs. Shwu-mei-Hong Chen, Graduate Instructor in Research on our staff, under the direction of Professor G. T. Satterly.

The report details research accomplished to recommend improved methods for state-wide vehicle counting. The work evaluated the existing vehicle counting methods in Indiana for estimating annual average daily traffic from short term counts. The research pertains to rural and suburban roads carrying 500 or more vehicles per day.

The improved methods suggested for the Indiana state-wide vehicle counting are basically procedures where statistical theories are applied to grouping continuous count stations and estimating standard deviations of AADT estimates. Recommendations are made for regrouping of continuous count stations and for establishing a seasonal control count station program. The recommended methods should, if implemented, raise the accuracy of the AADT estimates at reduced costs for the continuous count station program.

The report is submitted as fulfillment of the objectives of this study.

Respectfully submitted,



G. T. Satterly, Jr.
Research Engineer

GTS:jrr

cc: A. G. Altschaeffl
W. L. Dolch
R. L. Eskew
J. D. Fricker
G. D. Gibson
W. H. Goetz
M. J. Gutzwiller
G. K. Hallock

D. E. Hancher
K. R. Hoover
J. F. McLaughlin
R. D. Miles
P. L. Owens
G. T. Satterly
C. F. Scholer
R. M. Shanteau

K. C. Sinha
C. A. Venable
L. E. Wood
E. J. Yoder
S. R. Yoder

IMPROVED METHODS FOR STATE-WIDE VEHICLE COUNTING

by

Shwu-mei Hong Chen
Graduate Instructor in Research

Joint Highway Research Project

Project No. C-36-54AA

File No. 3-3-27

Prepared as Part of an Investigation

Conducted by

Joint Highway Research Project
Engineering Experiment Station
Purdue University

in cooperation with the

Indiana State Highway Commission

Purdue University
West Lafayette, Indiana

May 13, 1981

ACKNOWLEDGMENTS

This research project has been aided by many persons, not all of whom can be acknowledged in this short space. The author wishes to thank all of the persons who contributed but are not recognized here.

The author is sincerely grateful for the assistance and guidance provided by her major professor, Gilbert T. Satterly. Appreciation is expressed to Professor Virgil L. Anderson and Mr. Tom Kuczek for their ideas and cooperative work on the statistical methods. Also, the suggestions of Professor Harold L. Michael and Mr. Sterling Bolyard of the ISHC Planning staff in formulating the research topic are appreciated.

Thanks are offered to the Officials of the Divisions of Planning, Traffic and Design in ISHC and the planning and research staff of the FHWA Indiana Division office for their generous cooperation in providing data, helpful directions and comments on the Indiana Statewide volume counting program.

Thanks are in order for the officials who are involved in statewide traffic volume counting programs in the following twelve states: Colorado, Florida, Georgia, Illinois, Michigan, Minnesota, New Mexico, New York, Oregon, Rhode Island, Utah and Wisconsin for valuable information in preparing this research report. And, a thanks goes to those responsible for traffic counting in the FHWA Washington office for directing the author to the states having good traffic volume counting programs.

The financial assistance of the Joint Highway Research Project is likewise acknowledged for making this research possible.

TABLE OF CONTENTS

	<u>Page</u>
LIST OF TABLES	viii
LIST OF FIGURES.	ix
ABSTRACT	x
CHAPTER I: INTRODUCTION	1
Background.	1
Objectives.	3
Scope	4
CHAPTER II: EXISTING INDIANA STATEWIDE VOLUME COUNTING PROGRAM.	5
Introduction.	5
Administration.	6
Continuous Count Station Program.	7
Coverage Count Station Program.	8
Seasonal Control Count Station Program.	13
Related Studies	13
Methods of Estimating AADT Volumes.	14
Presentation of Traffic Volume Data	17
Uses of Traffic Volume Data by ISHC	17
CHAPTER III: STATEWIDE VOLUME COUNTING PROGRAMS IN OTHER STATES	19
Introduction.	19
Administration.	20
Collection.	20
Processing.	26
Presentation.	33
CHAPTER IV: ANALYSIS OF INDIANA'S EXISTING VOLUME COUNTING PROGRAM.	34
Introduction.	34
Agency Needs Study.	34
General Description.	34
Design Needs	35
Traffic Control Needs.	36

TABLE OF CONTENTS (Continued)

	<u>Page</u>
Administration.	37
Collection.	38
Processing.	40
Presentation.	41
Application	41
CHAPTER V: DEVELOPMENT OF IMPROVED METHODS FOR STATEWIDE VEHICLE COUNTING ON THE STATE RURAL HIGHWAYS WITH AADT VOLUMES GREATER THAN 500.	42
Introduction.	42
Statistical Analysis of Traffic Volume Variation	
Information.	44
Mathematical Models.	44
Federal-Aid Primary System	51
Interstate System.	58
Federal-Aid Secondary System	59
Grouping of Continuous Count Stations	61
Determination of Adequacy of the Continuous Count	
Station Program.	62
Treatment of Suburban Road Sections	71
Introduction	71
Statistical Analysis of Traffic Volume Variation	
Information	73
Determination of Adequacy of the Suburban Continuous	
Count Station Program	76
Treatment of Special Traffic Routes	78
Recommendations for the Statewide Vehicle Counting.	79
Continuous Count Station Program	79
Seasonal Control Count Station Program	82
Coverage Count Station Program	83
Estimation of Benefits of the Improved Methods.	85
CHAPTER VI: CONCLUSIONS	86
Summary	86
Recommended Statewide Vehicle Counting Program for Indiana.	87
Continuous Count Station Program	87
Seasonal Control Count Station Program	87
Coverage Count Station Program	89
Recommendations for Further Studies	90
FOOTNOTES.	91
BIBLIOGRAPHY	93

TABLE OF CONTENTS (Continued)

	<u>Page</u>
APPENDICES	97
Appendix A: Organization Chart of the ISHC Division of Planning	97
Appendix B: Mileage of 1980 Functional Systems by Jurisdiction in Indiana	98
Appendix C: Mileage of 1976 Realigned Federal-Aid Highway Systems in Indiana	100
Appendix D: Special Traffic Routes Study	101

LIST OF TABLES

<u>Table</u>		<u>Page</u>
1	Existing Continuous Count Station Locations.	9
2	1975 Highway Mileage Summarized by State and Geographic Area.	21
3	1975 Daily Vehicle-Miles of Travel (in Thousands) Summarized by State and Geographic Area.	22
4	Number of Control Stations by State.	25
5	Scheduling of Seasonal Control Counts by State	27
6	Scheduling of Coverage Counts by State	28
7	Data Retrieval System for Continuous Counts by State . .	29
8	Type of Counts Analyzed by Computer Programs by State. .	30
9	ANOVA Table for the Two-Factor Effects Study	49
10	Standard Deviations of Percent Error of AADT Estimated by Use of Proposed vs. ISHC Group Mean Factors for Rural Groups	67
11	Standard Deviations of Percent Error of AADT Estimated by Use of Proposed vs. ISHC Group Mean Factors for a Single Suburban Group.	77
12	Standard Deviations of Percent Error of AADT Estimated by Use of Proposed vs. ISHC Group Mean Factors for Two Suburban Groups.	77
13	Proposed vs. ISHC Group Distribution of the Continuous Count Stations	81
14	Proposed Continuous Count Station Program.	88

LIST OF TABLES (Continued)

<u>Appendix Table</u>		<u>Page</u>
B.1	1980 Functional System Mileage by Jurisdiction--Rural. .	98
B.2	1980 Functional System Mileage by Jurisdiction--Urban. .	99
C.1	Mileage of Realigned Federal-Aid Highway Systems of Indiana (as of December 31, 1976).	100

LIST OF FIGURES

<u>Figure</u>		<u>Page</u>
1	Existing Continuous Count Station Locations.	12
2	Comparison of Monthly Variations in Traffic Volume Between Rural and Suburban Sections on Route U.S. 31 for 1976	72

Appendix

<u>Figure</u>		
D.1	Coal Production Areas of Indiana	104
D.2	Coal Traffic on State Highway System	107
D.3	Summer Recreation Traffic on State Highway System. . . .	109
D.4	Lincoln Heritage Trail Route in Indiana.	110

ABSTRACT

Chen, Shwu-mei Hong. M.S.C.E., Purdue University, December 1979.
Improved Methods for State-Wide Vehicle Counting. Major Professor:
G. T. Satterly.

The purpose of this research is to evaluate the existing counting methods in Indiana for estimating annual average daily traffic from short-term counts and to determine whether existing procedures can be improved in accuracy and cost. This research pertains to rural and suburban roads carrying 500 or more vehicles per day.

An analysis of existing volume counting programs in Indiana, the other states in FHWA Region 5 and those states which were indicated by FHWA to have good counting programs, was performed and acted as a background study for recommendations for improved methods for the Indiana statewide vehicle counting program.

The improved methods suggested for the Indiana statewide vehicle counting are basically procedures where statistical theories are applied to grouping continuous count stations and estimating standard deviations of AADT estimates. The improved methods should, if implemented, raise the accuracy of the AADT estimates at reduced costs for the continuous count station program.

Recommendations are made for regrouping of continuous count stations, for establishing a seasonal control count station program.

CHAPTER I

INTRODUCTION

Background

One measure of the service provided by a highway facility or system is its usage. This usage is normally expressed in terms of traffic volumes - annual average daily traffic (AADT). AADT information is necessary for planning, design, maintenance, traffic control, programming and general administration of the highway program. These AADT estimates can be used to:

1. serve as a basis for forecasting traffic volumes,
2. provide information to determine design hour traffic volume (DHV) needed for geometric highway design purposes,
3. provide an indication of growth trends, and
4. determine vehicle-miles of travel (VMT) on various categories of highway systems.

To obtain true values of AADT, it would be necessary to count traffic continuously for a whole year on every section of road. This would be prohibitive to implement in practice from a cost standpoint. On the other hand, an estimate of AADT made by an experienced administrator could be unreliable. Thus, a compromise must be made between accuracy and cost in accordance with realistic needs. Various statistical methods may be used to develop sampling techniques to produce a desired balance between accuracy of results and cost of the traffic volume counting program.

The application of statistical methods in establishing traffic volume counting programs was first used in about 1951. Its use in several states has proved to be successful in gathering the same type of data as previously gathered but with a savings in manpower or the obtaining of more accurate and additional information for the same cost. Stimulus for the application of modern statistical methods in traffic volume counting programs was due to the following reasons:

In the past there has been little application of sampling techniques to the selection of control stations (continuous count or seasonal control count stations) (1). Using experience and judgment highway engineers selected locations of control stations to represent the largest mileage of primary highways. No numerical measures were used to describe the words "to represent" in the sense of monthly expansion factors.

Many states have encountered financial difficulties due to increasing traffic data needs along with escalating costs and/or budget cutting. The application of statistical methods to traffic counting can provide the states with a more economical and accurate method than subjective judgment or personal experience can.

A statistical approach can provide each state with a systematic basis for answering the key questions as to number and location of stations, length and frequency of counts and accuracy of results.

Recently, the Federal Highway Administration (FHWA) recommended that the Indiana State Highway Commission (ISHC) improve their existing traffic counting program to meet current needs for traffic volume data within the limited financial support (2). This research

was, therefore, proposed to analyze the existing program and produce an efficient vehicle counting method for the ISHC.

Objectives

This research project was conducted to achieve the following objectives:

1. determine the current and potential uses of traffic volume information by various agencies in the State of Indiana.
2. analyze the traffic volume information from the continuous count stations on the Indiana Statewide Highway System in the rural and suburban areas by statistical tools.
3. evaluate present statewide vehicle counting programs in the states in FHWA Region 5 and in other states which have good programs in terms of administration, collection, processing, presentation and application of traffic volume information.
4. develop and test improved cost-effective techniques and procedures (but not including an examination of the equipment used in collecting traffic counts) for sampling and expanding traffic counts that will produce estimates of acceptable accuracy for design, programming and administrative purposes.

The achievement of these objectives would provide the ISHC with suggestions for traffic counting methods to produce more reliable and detailed traffic data than the present program without an increase of costs and with information concerning the requirements (needs) for traffic volume data of various agencies in the state.

Scope

This research project was conducted to improve statewide vehicle counting methods on Indiana state highways in rural and suburban areas with AADT volumes greater than 500 vehicles.

The emphasis of the research was the improvement of counting procedures concerning adequacy of number and location of permanent count stations and in estimation methods of AADT volumes. The data basis for the development of the improved methods was traffic volume information from continuous count stations in Indiana.

To develop improved methods, the statewide volume counting programs in Indiana and the other states in FHWA Region 5 and other states which were indicated by the FHWA to have good counting programs were reviewed.

CHAPTER II
EXISTING INDIANA STATEWIDE VOLUME COUNTING PROGRAM

Introduction

The Indiana statewide traffic volume counting program was designed in the 1930's by the Indiana State Highway Commission. This program has remained basically the same for a number of years, except for some changes made during recent years in the following two areas.

1. Permanent Count Stations (continuous count stations or ATR's):

A majority of the permanent count stations have been in existence since the early 1940's. There were twenty-eight permanent count stations in 1968. They remain unchanged until 1977. Permanent Count Station 34-A, on a county road in Allen County, was discontinued because of problems with the inductance loops in the pavement. A new station, 2262-A, was put in operation on Spring Street in New Albany in 1978.

2. Grouping of Permanent Count Stations: The 28 permanent count stations were prior to 1977 classified into five groups:

- I. State Roads in Rural Areas other than in resort and mining areas.
- II. State Roads in Rural Resort Areas.
- III. State Roads in Mining Areas.
- IV. State Roads in Suburban Areas.
- V. Local Roads in Rural Areas.

A new grouping was set up in January 1978. The new grouping was established according to the "Guide for Traffic Volume Counting Manual" (3). The new grouping was required because the old groups did not align themselves according to a functional classification.

A FHWA review (4) suggested that more economical, efficient, and effective counting operations are needed to meet the requirements for traffic volume data by many agencies such as the Divisions of Planning, Design and Roadside Development. An understanding of the existing program is necessary for the development of improved methods. With the FHWA review report as a background document, the detailed description of the existing Indiana statewide traffic volume counting program follows.

Administration

The Indiana statewide traffic volume counting program is conducted within the ISHC's Division of Planning, specifically, Traffic Statistics under the Planning Statistics Section. Like many other states, Indiana's volume counting program represents a significant portion of the state planning budget for Highway Planning, Research and Planning (HPR and PL) funds. The volume counting work, not including vehicle classification and weight studies and additional counting by the cities and MPO's, utilizes about 19 percent of the total cost estimated for the state's HPR-PL planning work programs in FY 1979.

The traffic counting program entails the routine collection of traffic volumes on state and U.S. marked routes plus the County Federal-Aid Secondary System. In addition, if special requests are made and

time permits, the planning agency will collect counts on other roads in urbanized areas and on other rural county and local roads, but not on a regular basis.

One other state agency, in addition to the Traffic Statistics Section, also collects volume data - the ISHC Division of Traffic. The purpose of this division's counting program is to collect volume counts for its special traffic studies. Its needs for volume data will be discussed in Chapter IV.

Other volume counts are performed by local agencies. Such local agencies are cities and MPO's. These programs are not addressed in this research.

Continuous Count Station Program

The automatic traffic recorders (ATR's) located at the continuous count stations operate continuously for 365 days of the year. Some are directional. The continuous count stations use loop detectors buried in the pavement, with the exception of one station where an ultrasonic detector is used.

The state currently operates and reports data from 28 locations. These include 23 locations on rural main roads, 2 locations on local roads, and 3 locations on suburban main roads.

The existing grouping of continuous count stations is by functional classification and includes the following five groups:

- I. Interstate - rural.
- II. Federal-Aid Primary (Arterial) - principal and minor - rural.
- III. Federal-Aid Secondary (major collector) - rural.
- IV. Urban Routes.
- V. Special Stations.

The continuous count station locations are listed by group in Table 1 and mapped in Figure 1.

The data from the ATR's are used to develop annual average daily traffic and monthly adjustment factors for the continuous count stations (ATR's). The AADT's are used to develop historical trends. The monthly adjustment factors are used to expand short time counts at coverage count stations to estimated AADT for the roadway links where the coverage counts were taken.

Although ATR data is computerized in its raw state, the majority of the process is manual.

Coverage Count Station Program

The coverage count station program provides a major body of count information. There are about 6,700 coverage count stations included in the state highway system, the county Federal-Aid Secondary system and the Federal-Aid Urban system (with an emphasis on state routes). These coverage counts are taken for a 48-hour duration generally between noon Monday and noon Friday on a county by county basis over, on an average, a five-year cycle.

Counting equipment for the coverage count stations uses tube type detectors.

The 48-hour coverage counts are adjusted by monthly adjustment factors to obtain estimated AADT's for the highway sections where the coverage counts were taken.

TABLE 1 : EXISTING CONTINUOUS COUNT STATION LOCATIONS

MAP NO. IN FIGURE 1	STATION NO. COUNTY	LOCATION	NOTES
GROUP I -- INTERSTATE SYSTEM			
1	172-A JACKSON	I-65 SOUTH OF SEYMOUR	NORTH-SOUTH TRAFFIC
2	3070-A HANCOCK	I-70 EAST OF GREENFIELD	EAST-WEST TRAFFIC
3	5474-A MONTGOMERY	I-74 UNDER OLD S.R. 55 BRIDGE	EAST-WEST TRAFFIC
GROUP II -- FEDERAL-AID PRIMARY (ARTERIAL) SYSTEM			
PRINCIPAL ARTERIAL SYSTEM :			
4	68-A DEARBORN	U.S. 50 WEST OF AURORA	EAST-WEST TRAFFIC
5	134-A ALLEN	U.S. 30 NORTHWEST OF FORT WAYNE	EAST-WEST TRAFFIC
6	173-A KNOX	U.S. 41 NORTH OF VINCENNES	COAL MINING ROUTE
7	254-B MARSHALL	U.S. 31 SOUTH OF PLYMOUTH	NORTH-SOUTH TRAFFIC
MINOR ARTERIAL SYSTEM :			
8	25-A NOBLE	S.R. 9 SOUTH OF ROME CITY	NORTH-SOUTH TRAFFIC
9	100-X LAKE	U.S. 41 SOUTH OF CEDAR LAKE	NORTH-SOUTH TRAFFIC
10	256-A PULASKI	U.S. 421 SOUTH OF MEDARYVILLE	NORTH-SOUTH TRAFFIC
11	262-A WHITE	U.S. 24 EAST OF WOLCOTT	EAST-WEST TRAFFIC
12	279-A ELKHART	U.S. 6 EAST OF NAPPANEE	EAST-WEST TRAFFIC

TABLE 1, CONT.

MAP NO. IN FIGURE 1	STATION NO.	CONTY.	LOCATION	NOTES
13	301-A	RIPLEY	U.S. 421 NORTH OF VERSAILLES	NORTH-SOUTH TRAFFIC
14	313-A	MORGAN	U.S.R. 67 SOUTHWEST OF JCT. WITH S.R. 39	NORTH-SOUTH TRAFFIC
15	319-A	DUBOIS	U.S.R. 56 EAST OF HAYSVILLE	EAST-WEST TRAFFIC
GROUP III -- FEDERAL-AID SECONDARY (MAJOR COLLECTOR) SYSTEM				
16	42-A	TIPPECANOE	U.S. 52 AT THE JCT. WITH S.R. 28	NORTH-SOUTH TRAFFIC
17	47-A	RANDOLPH	S.R. 1 SOUTH OF FARMLAND	NORTH-SOUTH TRAFFIC
18	59-A	HANCOCK	U.S. 40 EAST OF GREENFIELD	EAST-WEST TRAFFIC
19	200-X	BARTHOLOMEW	U.S. 31 EIGHT MILES NORTH OF COLUMBUS	NORTH-SOUTH TRAFFIC
20	5420-A	MONTGOMERY	U.S. 136 WEST OF CRAWFORDSVILLE	EAST-WEST TRAFFIC
21	7047-A	RUSH	COUNTY ROAD FROM CARTHAGE TO MAYS	AADT LESS THAN 500
GROUP IV -- URBAN ROUTES				
22	40-A	TIPPECANOE	S.R. 25 SOUTH OF LAFAYETTE	URBANIZED AREA
23	45-B	DELAWARE	OLD S.R. 67 SOUTH OF MUNCIE	URBANIZED AREA
24	72-A	JACKSON	U.S. 31 SOUTH OF SEYMOUR	SMALL URBAN AREA, POPULATION 5,000-24,999
25	73-A	KNOX	OLD U.S. 41 NORTH OF VINCENNES	SMALL URBAN AREA, POPULATION 5,000-24,999

TABLE 1, CONT.

MAP NO. IN FIGURE 1	STATION NO.	COUNTY	LOCATION	NOTES
26	2262-A	FLOYD	SPRING STREET (S.R. 62) OF NEW ALBANY	URBANIZED AREA
GROUP V -- SPECIAL STATIONS				
27	74-A	SULLIVAN	S.R. 54 EAST OF JCT. WITH U.S. 41	COAL MINING AREA
28	281-A	KOSCIUSKO	S.R. 13 SOUTH OF NORTH WEBSTER	SEASONAL SUMMER ACT

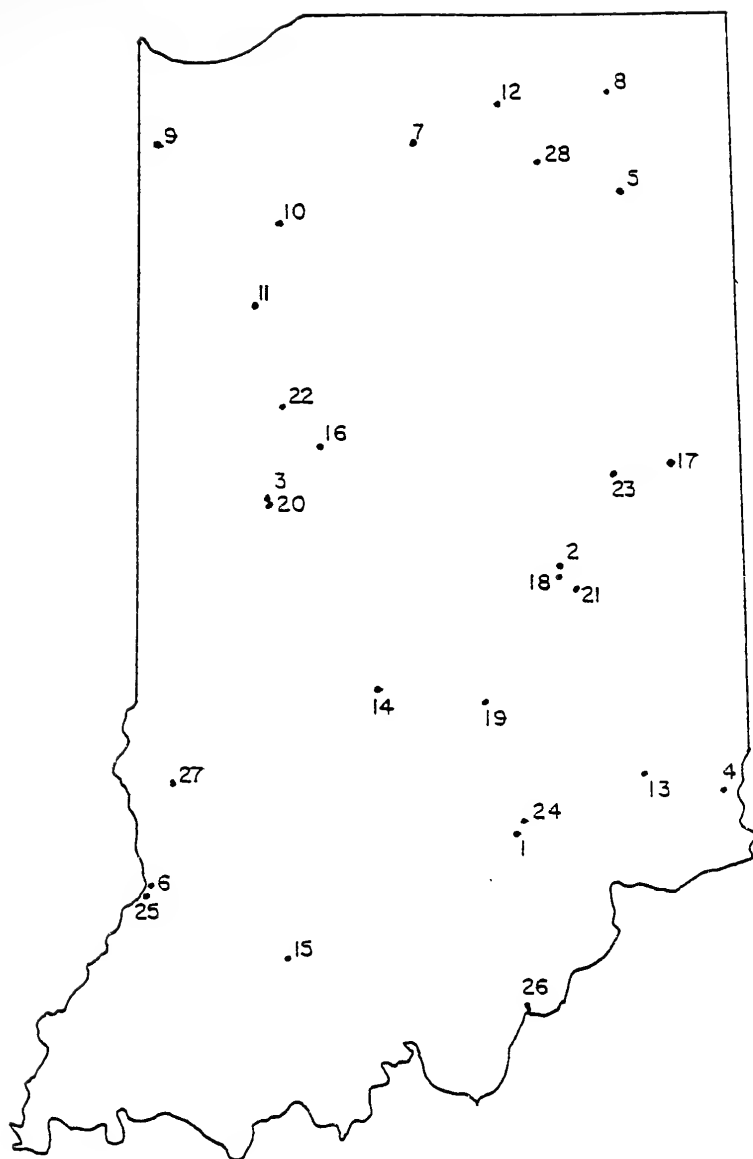


FIGURE 1 EXISTING CONTINUOUS COUNT STATION LOCATIONS
(IN INDIANA)

(For Station Numbers and Descriptions See Table I)

Seasonal Control Count Station Program

The seasonal control station system is being developed around the functional classification with an attempt to identify particular problem areas, such as areas of special seasonal variations. Two seasonal control stations were established in 1978 to operate for a full week during each month or season. They are located within two urbanized areas, on I-94 in Northwest Indiana and on I-65 in Indianapolis.

Counting equipment for all seasonal control stations includes loop type detectors.

The data collected will be used to make seasonal adjustments, similar to monthly adjustment factors, or evaluate the assignment of roads to particular groups.

Related Studies

The following related studies, which are also conducted in the Division of Planning, are not reviewed at length and are only briefly mentioned in this section.

1. Vehicle Classification Study: Vehicle classification counts are done yearly to determine the frequency distribution and trends of vehicles by type for various road sections of the highway system in the state.
2. Vehicle Weight and Characteristics Study (Biennial truck-weight study): This study was initiated during the summer of 1977 and will be performed during odd numbered years. Vehicle weight data is collected to determine the magnitude and

frequencies of axle loads and total weights of vehicles using the highways and streets in the state.

3. Special Traffic Studies: Special requests for traffic counts from within the ISHC and outside agencies are accommodated as possible. Since these requests cannot be supplied from the basic traffic volume data, the work program includes an allowance for numerous special counts, which are not routine and vary considerably in type, size, scope and purpose. Many of these special requests are of an emergency nature and cannot be anticipated. Such requests are, however, minimal, constituting two or three percent of the portable traffic counting activities.

Methods of Estimating AADT Volumes

The expansion factors (adjustment factors) for adjusting coverage counts to AADT estimates are group mean values of monthly adjustment factors. The methods of estimating AADT volumes used by the ISHC are approximately in conformity with the FHWA "Guide for Traffic Volume Counting Manual" (5). Deviations from this manual will be discussed in Chapter IV.

The procedures for estimation of AADT volumes by the ISHC are described in detail as follows:

1. A monthly adjustment factor is computed for each continuous count station for each month. It is the ratio of the AADT to the monthly average weekday traffic. The monthly average weekday traffic is computed from all the weekdays except Fridays in a month for the continuous count station.

2. The 24-hour averages of the 48-hour coverage counts are calculated. The 48-hour coverage counts are taken on weekdays, usually between noon Monday and noon Friday.
3. All the continuous count stations (in total, 28) are grouped as per the "Guide" without considering functional grouping. The grouping steps are outlined below:
 - a. Using the data for the previous year arrange the monthly adjustment factors for each month in ascending order.
 - b. For each month determine a set of stations such that the difference between the smallest and the largest monthly factor does not exceed the range of 0.20 in the values of the factors. For each month determine from several possible sets that set having the largest number of stations. Such a set will probably not be the same for each of the twelve months. That is, groupings tend to vary from month to month.
 - c. From the twelve previously determined sets, select one set that contains those stations common to all the twelve sets. In addition to these stations, a few additional stations are assigned to the set, though they have a factor which is outside of the 0.20 range in some months. Investigations have shown that special conditions can cause an abnormal change in traffic volumes for a month or two and study of the data for previous years indicated that these added stations had factors that would have placed them within the set determined from current

data. A set of stations determined by such a procedure is called a group.

- d. Steps b and c are repeated considering those stations that have not been included in the first group, and a second group is selected. Steps b and c are repeated a number of times until only those stations with extreme monthly adjustment factor values remain ungrouped. These stations are placed in a group entitled "Special Stations".
 - e. The resultant groups have been found to fit the functional classification designations, mentioned in the "Continuous Count Station Program" section of this chapter.
4. For each group compute the average of the monthly adjustment factors for each month to arrive at the group mean monthly adjustment factor. Some stations in a group, however, are not included in the computation of the mean factor for a particular month. That is, those stations having a factor outside the 0.20 range of the group for that month are not included.
 5. The group mean of the monthly adjustment factors for each month is used as an adjustment factor that would be applicable to 24-hour averages of 48-hour counts on weekdays.
 6. The average counts, if outdated because of the 5-year cycle used in obtaining coverage counts, are updated to the current year by a traffic growth factor determined from the ATR group to which the coverage counts have been assigned.

7. The updated coverage counts are multiplied by the same year mean monthly adjustment factor of the group to which the coverage counts are assigned to obtain an estimated AADT for the roadway section where the coverage count was taken.

Presentation of Traffic Volume Data

Reports transmitted to the Washington office of FHWA, as required by the FHWA "Highway Planning Program Manual" (6), include:

1. Average daily traffic for the month from each continuous count station.
2. Monthly toll facility data.
3. Hourly volumes for each continuous count station.
4. Daily and weekly volumes and summaries for each continuous count station.
5. Information required by FHWA for the annual updating of the traffic flow maps of the Interstate Traveled-Way.
6. State traffic flow maps. The Indiana state traffic flow map is currently produced about every three years.
7. Traffic logs.

There are no other summaries of traffic volume information prepared by the state.

Uses of Traffic Volume Data by ISHC

1. Program planning utilizes traffic statistics data to compile various requested traffic statistics data for the ISHC Design Division for geometric design purposes.
2. Traffic statistics data is used to prepare traffic flow maps.

3. Traffic statistics data is supplied by the ISHC for highway needs studies.
4. Traffic statistics data is supplied by the ISHC for the Interstate Cost Estimate-104(b)5 Study.
5. Traffic statistics data is utilized to respond to private and public requests for count data at specific locations.
6. The traffic volume statistical data reports, as mentioned in the previous section, "Presentation", are transmitted to the FHWA.

CHAPTER III

STATEWIDE VOLUME COUNTING PROGRAMS IN OTHER STATES

Introduction

The volume counting programs in other states were reviewed in this research. These states are those in FHWA Region 5 and those which are considered by the FHWA to have good vehicle counting programs. These two categories of states are described below:

1. Six states in Region 5: Illinois (IL), Indiana (IN), Minnesota (MN), Michigan (MI), Wisconsin (WI), and Ohio (no information available).
2. Ten states having good traffic volume counting programs: Colorado (CO), Florida (FL), Georgia (GA), Michigan (MI), New Mexico (NM), New York (NY), Oregon (OR), Utah (UT), Wisconsin (WI), and Montana (no information available).

There were nine states which have good vehicle counting programs and which made information available. These nine states plus Illinois, Minnesota, and Indiana are reviewed in this chapter.

The vehicle counting programs of these states will be analyzed for different work categories. It should be kept in mind that each state has its own problems concerning traffic volume information. Thus, it is difficult to assess these states' programs based on the objectives of this research program. The emphasis of this review will be directed toward understanding the current counting techniques used in these states, especially those having good programs.

This review primarily deals with the procedures involving three basic types of counts, continuous counts, seasonal control counts, and coverage counts. Special counts and the other related studies are not included in this review. The information for this review was collected from the twelve states' highway departments in late 1978.

Tables 2 and 3 contain highway mileage totals and daily vehicle-miles of travel (DVMT) respectively for each state by geographic area (7).

Administration

The statewide traffic volume counting programs in all these states, except Oregon, are conducted under the state highway departments' planning agencies. Oregon's statewide traffic volume counting program is conducted within the Traffic Unit, but under the Operations division, not the "Policy and Program Development" division.

In most of these states, other agencies, state and/or local, also collect volume data. One of the major efforts in their administrative programs is to coordinate the statewide volume counting programs with those of other agencies.

Collection

The determinant factors affecting a state's collection program for volume counts are as follows:

1. The three basic fundamentals of traffic counting programs - the objectives of the program, degree of accuracy required and costs involved.

TABLE 2 : 1975 HIGHWAY MILEAGE SUMMARIZED BY STATE AND GEOGRAPHIC AREA

STATE	IL	IN	MN	MI	WI	CO	FL	CA	NM	NY	OR	UT
RURAL HIGHWAY	103979	73822	112258	91330	93191	69875	57908	86862	45091	74077	86452	41893
URBAN STREET	26167	15580	11491	24662	11525	8216	33024	13655	4505	33667	7515	3511
TOTAL MILES	130146	89402	123749	115992	104716	78091	90932	100517	49596	107744	93967	45404

TABLE 3 : 1975 DAILY VEHICLE-MILES OF TRAVEL (IN THOUSANDS) SUMMARIZED BY STATE AND GEOGRAPHIC AREA

STATE	IL	IN	MN	MI	WI	CO	FL	GA	NM	NY	OR	UT
RURAL HIGHWAY	58339	48795	37699	58252	39567	22725	44198	70065	16554	71752	25857	9790
URBAN STREET	108435	47135	36841	101120	38745	22776	61272	50867	10616	145328	17634	12263
TOTAL DUMT	162774	95930	74540	159372	78312	45501	105470	120932	27170	217080	43491	22053

2. Physical conditions such as highway mileage, vehicle miles of travel, population data, land area and number of road sections.
3. Administrative factors such as highway mileage by jurisdictional system, counting operation arrangements, counting personnel and equipment available for collection.
4. Selection methods of count stations, especially continuous count stations and seasonal control stations.

The three basic types of counts, which are regularly taken, are continuous counts, seasonal control counts and coverage counts. Some states use other names for these counts. For purposes of comparison and analysis, we, by definition, have assigned only the names, continuous counts, seasonal control counts and coverage counts for the three basic types of counts. For example, in Utah, the 21 urban stations maintained for a period of seven days each month in areas classified as urban will be treated as seasonal control stations. In Michigan, the 1000 "A" stations counted 4 times a year for 96 hours each time will be treated as seasonal control stations, while the 8000 "C" stations counted once a year for 48 hours each time as coverage count stations. Also, in Florida, the 24-hour traffic counts at approximately 10,000 rural and urban locations are taken once each year, and it is appropriate to treat these urban and rural counts as coverage counts.

The collection program by state is described for the principal items listed below:

1. Number of Count Stations: The number of coverage count stations depends primarily on the number of road sections to be counted in the states, while the numbers of continuous

count and seasonal control stations basically depend upon the objectives, accuracy required and costs of the individual programs. Table 4 shows the numbers of these two kinds of control stations by state.

2. Location of Count Stations: The locations of count stations by the various classifications are stated as follows:
 - a. In geographic classification, all states take regular counts on rural and urban highways. The difference is the extent of coverage of each state's counts.
 - b. In administrative classification, all of the states take regular counts on the state highway systems, and most of them also take counts on County Federal-aid systems. Most of the states do not take regular counts on local systems, but some states such as Illinois, New Mexico and Utah do.
3. Method of Selecting Stations: Most of the states use the judgment of an administrator or historical precedent to select the location of continuous count control stations. Two states, Georgia and New York, have tried to select the control count station locations which statistically represent the traffic patterns for the entire highway system to be counted.
4. Scheduling of Counts: The scheduling of counts, including duration and frequency of counts, for continuous, seasonal control and coverage counts is as follows:
 - a. Continuous count stations for every state count vehicles for continuous long periods of time, usually at least several years.

TABLE 4 : NUMBER OF CONTROL STATIONS BY STATE

STATE	IL	IN	MN	MI	WI	CO	FL	GA	NM	NY	OR	UT
CONTINUOUS COUNT STATIONS	60 TO 75	28	103	93	63	67	87	59	43	63	110	58
SEASONAL CONTROL STATIONS	100 TO 200*	2	0	1000	2000*	0	0	68	114*	0	0	21
TOTAL CONTROL STATIONS	160 TO 275	30	103	1093	2063	67	87	127	157	63	110	79

Notes:

IL: The State has 300-400 "inactive seasonal control stations" where counts are taken for one full week each year for providing an effective means of monitoring overall changes in travel at minimum costs.

WI: The number, 2000, includes 8 month seasonal and 12 month control stations.

NM: The State has 210 "inactive seasonal control stations" in 72 incorporated places for updating vehicle miles in urban areas.

- b. Seasonal control count stations for most states count vehicles for repeated intermittent periods of time. These periods, usually of consecutive seven days duration, are repeated on a monthly or seasonal basis. Table 5 shows the details about this type of count scheduling for the seven states which have seasonal control count stations. Wisconsin's seasonal control stations are counted once every three years. Five states take seasonal control counts on an annual basis. Indiana's seasonal control station program, is still in the developing stage.
- c. Coverage count stations count vehicles for various short periods of time on different time cycles, depending on the states. Coverage count durations and frequencies are indicated in Table 6.

Processing

Facilities for processing of volume data, estimation methods of AADT volumes and a related axle correction factor are discussed here.

1. Facilities for processing of volume data are principally data retrieval systems, either telemetry or manual, and computer programs for analysis of volume data, either control counts only or all available types of basic counts. In each of the 12 states, short-term counts (coverage or seasonal control) are returned from the field by manual delivery. Tables 7 and 8 give the other desired information on this category by state.

TABLE 5 : SCHEDULING OF SEASONAL CONTROL COUNTS BY STATE

STATE	IL	IN	MI	WI	GA	NM	UT
DURATION	A WEEK	A WEEK	96 HOURS	A WEEK	A WEEK	A WEEK	A WEEK
FREQUENCY	MONTHLY*	NA	SEASONALLY	MONTHLY*	MONTHLY	SEASONALLY	MONTHLY

Notes:

IL: The seasonal control stations where portable counters are used take counts for the nine months except winter months; while where loop counters are used for all twelve months.

WI: The seasonal stations take counts for the eight months except winter months.

TABLE 6 : SCHEDULING OF COVERAGE COUNTS BY STATE

STATE	IL	IN	MN	MI	WI	CO	FL	GA	NM	NY	OR	UT
DURATION	24 HRS A WEEK	48 HRS	48 HRS	48 HRS	48 HRS	24 HRS 48 HRS A WEEK	24 HRS	24 HRS	9 HRS* 48 HRS	48 TO 96 HRS	24 HRS	48 HRS
FREQUENCY (YEAR CYCLE)	5	5	2 6*	3	3	2	1 1/4*	1	5	3	2	3

Notes:

MN: For the County metropolitan area and rural state trunk highway system, the coverage counts are taken on a 2-year cycle. For County highways, the coverage counts are taken on a 6-year cycle.

FL: The State takes 24-hour counts four times each year at 3-month intervals on sections where AADT is greater than 2000 in rural areas, where State maintained roads enter the corporate limits of cities, and where there is a significant change in the traffic pattern within cities.

NM: The 9-hour period coverage counts are obtained by manual counts to give reliable information on turning movements, the peak hour volumes, and vehicle classification, and for computing AADT.

TABLE 7 : DATA RETRIEVAL SYSTEM FOR CONTINUOUS COUNTS BY STATE

STATE	IL	IN	MN	MI	WI	CO	FL	GA	NM	NY	OR	UT
TELEMETRY				X		X	X	X	X			
MANUAL	X	X	X		X		X		X	X	X	X

2. The estimation methods of AADT volumes for each of the 12 states are summarized in terms of the characteristics of adjustment factors below:

- a. Monthly group mean factor:

States observed: IL, IN, MN, WI, CO, NY, OR, and UT.

The mean monthly adjustment factor is determined using data from a control station group. WI includes data from seasonal control stations to compute group mean factors. IL and UT use continuous count stations data plus data from seasonal control stations in some cases, to compute group mean factors. The other five states, having no seasonal control stations, use data from continuous count stations only to get group means.

In UT, whenever the grouping process appears erratic, individual station ATR data are used for factoring.

The method suggested in the "Guide", that is, the 0.20 rule for the range of monthly factor values in a group, is used in most of the states, such as IL, IN, WI, CO, NY, and UT.

Old grouping methods are used in the remaining two states, MN and OR. MN groups the stations by road classification while OR groups by area of the state.

- b. Monthly individual control station factor:

States observed: MI.

MI uses a monthly adjustment factor from one control station, not a group of control stations.

c. Monthly and weekday group mean factors

States observed: GA.

In GA a coverage count is adjusted twice, first by a monthly group mean factor and secondly by a specific weekday group mean factor in the same month. Continuous and seasonal control stations contribute to the group means.

Road segments are first divided into rural routes, urban routes, and recreation area access roads. Rural routes are further divided into Interstate routes and non-Interstate routes. And, non-Interstate routes are further subdivided into those with AADT greater than 500 vehicles and those with AADT less than 500 vehicles. As far as rural routes are concerned, Interstate routes and non-Interstate routes with AADT greater than 500 are further grouped by the 0.20 rule, while non-Interstate routes with AADT less than 500 are further grouped according to terrain characteristics, i.e. mountain, piedmont and coastal areas of Georgia.

d. Individual weekday factor from an individual control station

States observed: FL and NM.

Individual weekday factors are computed by dividing AADT for a control station by its simultaneous daily count during the day(s) when a coverage count is to be taken.

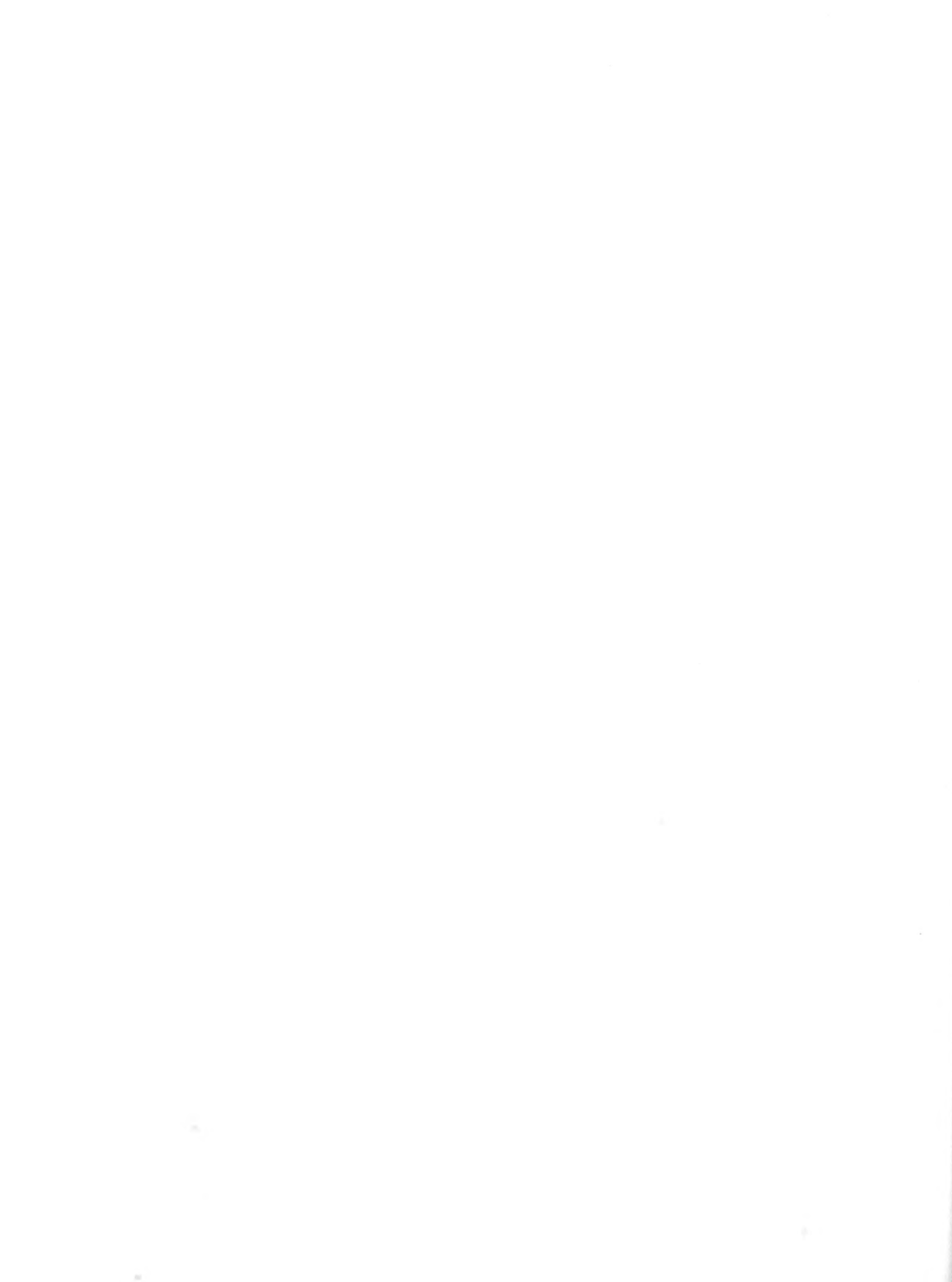
3. In some states axle correction factors are used together with seasonal adjustment factors to correct tube-type machine counts. This factor is derived from vehicle classification counts. This factor is used in IL, CO, NM, and NY. The other

states did not indicate whether or not they used such a correction factor. Indiana has used the factor to reduce errors in estimating future AADT volumes.

Presentation

Except for reports required by FHWA, not every state publishes reports of count data on a regular basis. Michigan publishes volume data on a monthly basis. The others, except Indiana, publish their volume data in reports on an annual basis. Indiana does not publish volume data.

1. States publishing all available types of count data in reports are: WI, CO, FL, NY, OR, and UT.
2. States publishing only continuous count data in reports are: MN, MI, GA, and NM.
3. The state publishing only seasonal control count data in reports is: IL.



CHAPTER IV

ANALYSIS OF INDIANA'S EXISTING VOLUME COUNTING PROGRAM

Introduction

A review of the existing statewide volume counting programs in Indiana and other states has indicated areas in which improvements might be made. With the aid of the 1978 FHWA review report (8), a more detailed review through meetings with various ISHC personnel was conducted. The findings from these reviews are discussed. Areas where improvements might be made in the present administrative procedures and technical programs and the evaluation of the use of volume data are discussed.

Agency Needs Study

General Description

This section discusses where and why traffic volume data are needed in several state agencies in addition to the Division of Planning. Such agencies are the Divisions of Traffic, Design and Roadside Development. The traffic volume data needs of the Program Planning Department and the Divisions of Design and Roadside Development are discussed in the same subsection "Design Needs". The volume data needs for traffic control of the Division of Traffic are discussed in another section. Appendix A shows an organization chart of the Division of Planning.

Design Needs

In addition to using volume data for programming of projects, the Program Planning Department, within the Division of Planning, acts as a clearinghouse for traffic volume data for other sections within the ISHC, primarily the Divisions of Design and Roadside Development for their design purposes. It utilizes raw coverage count data, adjustment factors and vehicle classification counts to compile various requested traffic statistics data for geometric design and environmental studies for the Design and Roadside Development Divisions, and sometimes, for special studies of the ISHC. A $\pm 10\%$ accuracy level for traffic data is important to the various estimates made by the Department.

The major traffic statistics data requested by these two Divisions are:

1. Current Average Daily Traffic (current ADT): It is defined as annual average daily traffic for the current year (current AADT).

Notes: AADT will always be referred to as ADT unless it is indicated as monthly ADT or weekly ADT.
2. Future Average Daily Traffic (Future ADT): It is defined as annual average daily traffic for the current year plus 20, and it is obtained by multiplying the current ADT by the 20-year expansion factor.
3. Future Design Hourly Volume (Future DHV): It is defined as design hourly volume for the current year plus 20, and usually it equals the 30th highest hourly volume of the current year plus 20.

4. Ratio of DHV to ADT, (K): It is used to obtain future DHV by applying to future ADT.
5. Trucks (T): They are expressed as percentage of DHV or percentage of ADT.
6. Directional Distribution of DHV (D): It is defined as one-way volume in predominant direction of travel expressed as percentage of total two way DHV. It is determined by field measurement.
7. Design Year Turning Movements: They are estimated for intersection and interchange designs.

The major traffic statistics data required by the Department itself for program planning, are current data in ADT volumes, vehicle classification counts, seasonal control counts and weekend counts on specific locations throughout the state in urban or rural areas. Sometimes, it is necessary for the Traffic Statistics Group to take special counts for more detailed information in particular problem areas, such as on roadway sections where unusual traffic volume variations result from recreational or shopping facilities.

Traffic Control Needs

Volume counts are needed on roadway sections and at intersections by the Division of Traffic for conducting traffic studies into the possible need for a change in traffic control. Traffic studies at intersections require volume counts by approach and by lane, if possible, and for turning movements in the intersection as well as classification counts of passenger vehicles and trucks. This information is used to help determine what type of traffic control is

warranted, whether any consideration should be given to installing or changing any channelization and timing and phasing of traffic signals and other traffic engineering measures.

Since the Planning Department's program does not include the gathering of this type of data the Traffic Division conducts their own traffic volume counting program to meet their data needs. It gathers data on an as-needed basis rather than on a routine basis.

Many times the volume count needs of the Traffic Division are of an emergency nature and cannot be anticipated either in time or space. It is, therefore, difficult for the Planning Division to satisfy these needs due to its limited manpower. The Division of Traffic makes limited use of the traffic volume data collected by the Division of Planning. It utilizes the AADT estimates for roadway sections from the Planning Division for accident studies and to verify or adjust data it has collected.

Administration

1. The traffic counting programs in urban areas, especially those of MPO's are not being well coordinated with the ISHC program.

Formal procedures for the routine sharing of traffic count data would assist all parties. The urban areas could use information gathered by the ISHC to monitor their transportation plans, while the ISHC could use urban counts as input to the INTRACS system, in developing the TA-1 Table and in the preparation of other FHWA reports that require VMT or other urban data.

It has been recommended by FHWA to establish procedures and an overall framework to coordinate the traffic counting program of the Division of Planning in ISHC with those of urban areas.

2. The traffic counting programs in the Division of Traffic are not being coordinated with the ISHC program in the Division of Planning.

It would be helpful to have a sharing of collected data. The Division of Traffic could use continuous count data for accident studies. It could also use a traffic map in conjunction with speed studies, accident rate studies and traffic signal warrant studies. Additionally, the Division of Planning could use traffic volume information at intersections for junction design.

Collection

1. A visual inspection of the existing ATR's indicates a geographic bias within functional classifications.

The ATR's on arterials are located in the northern and southern one-third of the state while the locations on major collectors are within the central one-third (Figure 1).

The number of ATR's on Interstate highways is not adequate to represent different conditions and travel characteristics. The locations show a geographic bias. There is no ATR station in the northern one-third of the state, and there is only one station in the southern part of the state (Figure 1).

2. The existing ATR groups indicate a bias of functional classification. Separately counting and estimating traffic volumes is necessary for high and low volume roads, rural and urban roads and roads with general and special traffic volume patterns. There are no permanent count station group classifications for state roads in urban areas, minor collectors and local roads.

The Federal-Aid Primary group contains 12 continuous count stations. One of them is located on a county road with AADT lower than 500 and the others are located on the state roads with higher volumes, above 500 AADT. The Federal-Aid Secondary group contains 6 continuous count stations. One of them is located on a coal traffic route while the others are on roads with normal traffic volume variation patterns.

3. The selection of control stations are not based on the results of statistical data analysis and careful consideration of all purposes served by these control stations. Utilization of statistical methods can reduce the number of continuous control counts for every ATR group and still maintain required accuracy levels.

The existing grouping of ATR's may not obtain statistically representative group mean expansion factors for coverage counts. Some of the ATR's may need relocating or eliminating. The adequacy of number and location of ATR's in every group should be evaluated through yearly checks as suggested by the FHWA (9). Probably further grouping in every group is needed to obtain more representative group mean factors by narrowing the difference among the expansion factor values of a group.

The assignment of proper road sections to the two Special Station groups has not been done yet. The group factors for the two special ATR stations are not used to expand coverage counts on the specific road sections.

Seasonal control stations can be used to supplement ATR's.

4. The present coverage counting program is made in a five-year cycle. This is one of the reasons causing errors in updated AADT estimates made from coverage counts. The FHWA has recommended a maximum cycle of three years for a coverage counting program.

In the scheduling of coverage counts, the season should be selected that most nearly represents the average traffic for the road section being counted.

There is a need to coordinate the length of coverage counts and adjustment factors with the consideration of cost so as to achieve a balance between cost and accuracy. Since the monthly adjustment factors are the ratios of AADT to monthly average weekday traffic, the coverage count duration might be extended from the present 48 hours to four consecutive weekdays if improving the accuracy level of AADT estimates is desirable taking into consideration the increased cost of obtaining the additional data.

If there are vehicle classification counts available at the ATR stations axle correction factors may be used to reduce the errors resulting from tube-type machine counts.

Weekly adjustment factors or even individual weekday factors may be applied to increase the accuracy of AADT estimates.

Processing

Program modernization in automation of collection and compilation of traffic counts is still in the very early stages.

A telemetry system for retrieving continuous count data from the field and computer programs for analysis of count data are needed to increase the efficiency and effectiveness of processing data.

Presentation

Except for the traffic flow map currently produced about every three years, traffic count data is not routinely analyzed or published.

It is desirable to publish the various volume data, including vehicle classification counts, in reports.

Application

There is a lack of communication and coordination between the users and collectors of traffic volume data.

Identification of uses of traffic count data in relationship to needs is necessary to determine if the data are responsive to the needs. The potential needs of the Traffic Division for the Planning Division's count data and vice versa should be identified to prevent duplicating volume counts, and make full use of volume count information. The existing and potential design and planning needs by the Divisions of Design, Roadside Development and other sections in the Division of Planning should be evaluated to determine if the Planning Statistics section's counting program is responsive to these needs.

It was not evident that the selection of projects by the Program Planning Department was heavily based on traffic patterns or trends established from the traffic counting program.

CHAPTER V
DEVELOPMENT OF IMPROVED METHODS FOR STATEWIDE VEHICLE
COUNTING ON THE STATE RURAL HIGHWAYS WITH AADT
VOLUMES GREATER THAN 500

Introduction

Most AADT values for a highway system are obtained by taking short term sample counts of traffic volumes on sections of the highway system. These coverage counts are then expanded into estimates of AADT by using adjustment factors, developed from continuous count stations. The problem is to develop improved procedures for sampling and expanding traffic counts at coverage count stations to produce estimates of AADT of acceptable accuracy at minimum cost.

The "Guide" (10) suggests that the sections of the highway system be divided into different categories as to

1. Geographic areas: rural and urban
2. Traffic volume patterns: general and special, and
3. AADT volume groups: three groups--AADT greater than 500, between 25 and 500, and less than 25.

This research is concerned with traffic counting on the state highway system on rural and suburban sections with 500 AADT or more.

The basis for the establishment of improved procedures is monthly adjustment factors developed from continuous count stations, as suggested in the "Guide" (11). Monthly traffic volume variations form

patterns which tend to persist from year to year on the same road sections. Thus groups with similar traffic patterns remain nearly intact for several years. The proper grouping of the sections of highway and location of continuous count stations based on the available information concerning factors affecting traffic variations are necessary for improved sampling methods involving application of the continuous count station group mean factors to coverage counts taken on individual sections of highway.

The ISHC has grouped the 28 continuous count stations in Indiana according to the "Guide", as shown in Table 1. However, some problems have been found in this preliminary division of the count stations for counting and estimating of traffic volumes. Station 173-A in the Federal-Aid Primary group is suggested to belong to Group V, special stations, because it is located on a coal haul route. Station 7047-A is located on a county road in the Federal-Aid Secondary group with AADT far below 500, and is not included in this research. Also, Station 2262-A, is located in the downtown area of a particular urban area and is also excluded from the analysis. The ISHC functional group distribution of the 26 stations is revised as follows:

<u>Functional Group</u>	<u>No. of Continuous Count Stations</u>
Interstate	3
Arterial (FAP)	11
Major collector (FAS)	5
Suburban Routes	4
Special stations--coal	2
Special station--recreation	1

No continuous count stations are presently located on minor collector roads or local roads in the rural areas. Therefore, the

above three rural groups, Interstate, Federal-Aid Primary and Federal-Aid Secondary and the suburban group are considered for the following analysis.

The following statistical analysis of continuous count stations (Automatic Traffic Recorders) information is performed on the basis of this group assignment of ATR stations to determine whether the existing ISHC grouping is sufficient to represent various traffic volume variation patterns for a more accurate estimation of AADT volumes at the coverage count stations.

With the statistical analysis as a basis, suggested improved methods are developed to produce a cost-effective counting program, resulting in more reliable traffic data than the present program at the same or reduced costs. The standard deviations of the AADT estimates are estimated to verify the improvement resulting from the "improved methods".

The improved methods deal primarily with the first four groups, i.e. rural and suburban roads. The traffic volume variation pattern of rural highways is much different from that of suburban roads. Therefore, the improved methods will be stated separately for rural and suburban roads.

The Special Station group will not be discussed in detail.

Statistical Analysis of Traffic Volume Variation Information

Mathematical Models

It is desired to establish groups of road sections having similar patterns of monthly traffic volume variation in the state. Road

sections which are determined to have such similar patterns provide the basis for the expansion of coverage counts taken at points on these sections within each group. In addition to the preliminary grouping by the ISHC, further analysis and grouping is performed in this research to get more representative continuous counts in each group for accurate estimation of AADT volumes from coverage counts. Common statistical models are utilized to perform the desired analysis for further grouping.

For such analysis and grouping, those factors considered to have an effect on traffic volume variation are studied. For each initially selected factor the ATR's can be placed in groups using the particular factor. The analysis determines whether or not the factor level means μ_j are equal. If they are not, this factor becomes a grouping factor.

Obviously, "month" is a grouping factor and its significant effects on seasonal volume variation are demonstrated later. In the state, coverage counts are taken in twelve months so there are twelve factor levels for the "month" factor. The other factors considered have two factor levels. Several such factors are proposed for the rural highways.

1. Traffic flow direction factor: The two factor levels are north-south traffic (NS) and east-west (EW) traffic.
2. Geographic location factor: Two factor levels for a vertical division of the state are eastern and western parts. Two factor levels for a horizontal division of the state are northern and southern parts. For recognition of such single-factor effects those stations located in the extreme areas of

these parts are selected for the analysis in most cases, and the abbreviations for these areas are respectively E, W, N, and S.

3. Functional classification factor: This factor is only for the Federal-Aid Primary group, which has two subgroups-- principal arterial (P) and minor arterial (M).

From a statistical standpoint, the usual practice is to use the "F" test with the "F" statistics as a decision criterion. The data for this type of test are monthly adjustment factors. The data for four years from 1975 to 1978 are used. For part of the analysis 1974 data are also used. The ISHC indicated that extreme weather conditions were encountered at all the ATR's during January and December in 1977 and January and February in 1978.

The following text describes two statistical models using the "F" statistics (F tests) which are applied to the statistical analysis of the ATR information on traffic volume variation.

1. Two-factor analysis of variance (ANOVA) model

This model is first applied to the preliminary determination of factor effects. Two factors originally considered to be significant among those aforementioned factors are the traffic flow direction factor with factor levels north-south (NS) and east-west (EW) and the geographic location factor with factor levels north (N) and south (S). There are four treatments in this model. The number of continuous count stations must be at least one for each treatment thus at least four stations are required for the whole model. All the rural groups except the Federal-Aid Primary group do not have enough stations for

the four treatments. Accordingly, the Federal-Aid Primary group is selected for the application of this model. Three or more factor models are prohibitive in our case because the existing number and location of the ATR's are not sufficient for the requirements of such models.

The procedure of the two-factor model analysis is shown below:

(1) the requirements for the model must be satisfied.

a. Normality

Experience has indicated that monthly adjustment factors are normally distributed (12).

b. Independence of error terms

The continuous count stations from which the monthly adjustment factors are determined are from the population of road sections and are approximately independent random samples. Actually a slight dependence exists for adjustment factors over 12 months at a station. This should not affect conclusions about non-month factors.

c. Equality of error variances

The Bartlett test is used to determine whether all the populations consisting of 48 monthly adjustment factors (12 months for each treatment) have the same variance. Transformation of raw data Y to $\frac{1}{Y}$, has been found to be able to equalize the variances if inequality is detected.

(2) Notations in the structure of the model are described below:

a. Set traffic flow direction as Factor D, geographic

location as Factor G, treatment (or group) as T, station as S, and month as M.

b. The number of stations in each group is summarized below:

		Factor D		
		NS	EW	total
Factor G	N	$4(n_1)$	$3(n_2)$	7
	S	$2(n_3)$	$2(n_4)$	4
total		6	5	11

c. The total number of observations will be twelve (months) times eleven (stations), i.e. 132, since every station has 12 different cases (months) in a year.

d. The two-factor ANOVA model is completed in Table 9. The Table is a special case of the general statistical two-factor ANOVA model.

(3) The decision rule for the F tests is generalized as follows:

At the level of significance α :

If $F^* \leq F(1 - \alpha; df_n, df_d)$, conclude the factor level means are equal; that is, conclude no significant factor effects exist.

If $F^* > F(1 - \alpha; df_n, df_d)$, conclude the factor level means are not equal; that is, the interested factor can be a grouping factor.

where α : value selected by the experimenter, in many cases, the value of 0.05 is suggested.

df_n : the degree of freedom for the statistic in the numerator of the F^* .

df_d : the degree of freedom for the statistic in the denominator of the F^* .

TABLE 9 : ANOVA TABLE FOR THE TWO-FACTOR EFFECTS STUDY

SOURCE OF VARIATION	SS	DF	MS	F*
BETWEEN GROUPS (TREATMENTS)				
FACTOR G	SST	3	MST = SST/3	
FACTOR D	SSG	1	MSG = SSG/1	F*
INTERACTION OF G WITH D	SSD	1	MSD = SSD/1	F*
ERROR 1 (BETWEEN STATIONS IN GROUPS)	SSGD	1	MSGD = SSGD/1	
FACTOR M	SSE1	7	MSE1 = SSE1/7	
INTERACTION OF T WITH M	SSM	11	MSM = SSM/11	F*
ERROR 2 (INTERACTION OF S IN GROUPS WITH M)	SSTM	33	MSTM = SSTM/33	
	SSE2	77	MSE2 = SSE2/77	
TOTAL	SSTO	131		

Notes:

F*: the test statistic for determining whether or not the group means of a factor, G, D, or M, differ.

2. Single-factor analysis of variance (ANOVA) model

The difference between this and the previously described models is the number of factors to be tested, as their titles indicate. The single-factor is simpler and can be applied to all the groups of ATR's because the number of stations required for the model is at least two for at least one factor level of the selected factor. Since Factor M (month) was shown to have significant effects by the use of the two-factor model, the single-factor model is used to perform the studies of the aforementioned factors with two factor levels.

The procedures for the single-factor model, similar to the two-factor model, are described as follows:

- (1) The same requirements as for the two factor model must be satisfied before the performance of the F tests.
- (2) The structure of this model is generalized as follows:

$$F^* = \frac{\frac{\sum_{j=1}^{12} (\bar{Y}_{1j} - \bar{Y}_{2j})^2}{\sigma_n^2} \div n}{\frac{n_d \hat{\sigma}_d^2}{\sigma_d^2} \div n_d} \quad (5.1)$$

where $\bar{Y}_{1j}, \bar{Y}_{2j}$: means for Factor levels 1 and 2 of a specific factor in Month j.

σ_n^2 : variance of the difference of the two factor level means; that is, the true value of SS (sum of square) in the numerator of F^* .

- σ_d^2 : variance of the two factor levels' populations assuming the two populations have the same variance; that is, the true value of SS in the denominator of the F^* .
- $\hat{\sigma}_d^2$: estimate of σ_d^2 ; that is a specific SS, which is the sum of the monthly variances for the factor level(s) having at least two stations as observations for each month. This SS can be found in the corresponding Bartlett test.
- n_n, n_d : degrees of freedom for the two SS's in the numerator and denominator, and $n_n = 12$, always.

- (3) The decision rule is the same as that in the two-factor model.

The results of the application of the two ANOVA models are described in the following subsections for various highway categories. The Federal-Aid Primary is studied first because results of the two-factor model application to the highway system can be helpful to other tests using the single-factor model.

Federal-Aid Primary System

Eleven continuous count stations in this system are within the analysis. Their locations and other information are indicated in Table 1 and Figure 1.

The two-factor ANOVA model is first applied to the data to determine whether the two selected factors are significant grouping factors and which of the two factors can be considered most significant among the factors to be tested under this highway category and the other two rural categories. The following test uses the two-factor model.

1. Test for determining which factor of the two selected factors has more significant effects.
 - a. two factors: traffic flow direction factor and geographic location factor with the division of the state into N & S.
 - b. stations observed: all of the eleven ATR's.
 - c. results: Note that the abbreviations in Table 9 are used here.

Factor D:	in 1978, $F^* = 1.24$	<	
	in 1977, $F^* = 5.99$	>	
	in 1976, $F^* = 5.21$	<	$F(0.95; 1,7) = 5.59$
	in 1975, $F^* = 6.05$	>	

Factor G:	in 1978, $F^* = 0.01$	<	
	in 1977, $F^* = 0.01$	<	
	in 1976, $F^* = 0.00$	<	$F(0.95; 1,7) = 5.59$
	in 1975, $F^* = 0.02$	<	

- d. conclusions: Factor D has caused significant effects on monthly volume variations for the years 1977 and 1975 but not for years 1978 and 1976. Factor G with N & S does not create effects, having F values far below the criterion value.

- e. remarks: The effects of Factor Month, at the same time, are determined to be significant in the model. The results of this factor test are
- in 1978, $F^* = 79.79 >$
- in 1977, $F^* = 57.84 >$
- in 1976, $F^* = 69.81 >$
- in 1975, $F^* = 64.46 >$
- $F(0.95; 11, 77) = 1.93$

The results of the two-factor ANOVA model application indicate that for the FAP category the subsequent tests can be started assuming that the traffic flow direction factor effects the grouping. The following tests, using the single-factor ANOVA model, determine the effects of the other factors under a certain traffic flow direction since the traffic flow direction factor has been shown to cause effects on the monthly traffic volume variation pattern of the Federal-Aid Primary system.

2. Test for Equality of the North and South Factor Level Means at a traffic flow direction factor level, EW.
 - a. factor: geographic factor with factor levels N & S.
 - b. stations observed: N -- 134-A and 279-A
S -- 319-A
 - c. results: in 1978, $F^* = 1.98 <$
in 1977, $F^* = 1.95 <$
in 1976, $F^* = 1.04 <$
in 1975, $F^* = 0.77 <$

$F(0.95; 12, 12) = 2.69$
 - d. conclusion: no effects exist

- e. remarks: other similar tests under the traffic flow direction NS, cannot be done because there is no station located in the extremely southern part in this case.
 - f. notes: This test is to determine whether there is difference in the traffic volume variation pattern between the two extreme geographic parts of the state, although no difference was found from the two-factor model between the northern and southern halves.
3. Test for Equality of the East and West Factor Level Means at a traffic flow direction factor level, NS.
- a. factor: geographic factor with factor levels E & W
 - b. stations observed: E -- 25-A and 301-A
W -- 100-X and 256-A
 - c. results: in 1978, $F^* = 0.61 <$
in 1977, $F^* = 1.03 <$
in 1976, $F^* = 4.98 >$
in 1975, $F^* = 2.13 <$
 $F(0.95; 12, 24) = 2.18$
 - d. conclusion: 1976 data show the existence of effects; 1975, 1977 and 1978 do not.
 - e. remarks: The results indicate that this geographic factor (E and W) has greater effects than the other geographic factor (N and S) in the previous test but the results are weak at best. There is a significant effect in 1976 only.

4. Test for Equality of the East and West Factor Level Means at a traffic flow direction factor level, EW.

a. factor: geographic factor with factor levels E & W

b. stations observed: E -- 68-A and 134-A

W -- 262-A and 319-A

c. results: in 1978, $F^* = 0.59 <$

in 1977, $F^* = 0.46 <$

in 1976, $F^* = 0.61 <$

in 1975, $F^* = 3.68 >$

$F(0.95; 12, 24) = 2.18$

d. conclusion: 1975 data show the existence of effects;
1976, 1977, 1978 do not.

e. remarks: This test indicates similar results to the preceding test's; that is, only one year shows that the geographic factor with factor levels E and W creates effects on the monthly volume variation. The two years, 1976 and 1975, are not those indicated to have the extreme weather conditions. 1977 and 1978 did have extreme weather.

5. Test for Equality of the Principal and Minor Arterial Factor Level Means at a traffic flow direction factor level, NS.

a. factor: functional classification factor with factor levels P & M

b. stations observed: P -- 254-B

M -- 25-A, 100-X, 256-A, 301-A and
313-A

c. results: in 1978, $F^* = 0.45 <$
 in 1977, $F^* = 0.40 <$ $F(0.95; 12,12) = 2.69$
 in 1976, $F^* = 0.41 <$
 in 1975, $F^* = 1.53 <$

d. conclusion: No effects exist

e. remarks: This test and the previous one indicate that the middle stations and western or eastern stations cannot be shown to be different in terms of traffic volume variation under the same flow direction EW. Therefore, the division of the state into the eastern and western halves at the EW traffic flow direction factor level does not seem reasonable.

8. Test for Equality of the Eastern and Middle Group Means at a traffic flow direction factor level, NS.

a. factor: geographic factor with factor levels E and Middle

b. stations observed: E -- 25-A and 301-A

Middle -- 254-B and 313-A

c. results: in 1978, $F^* = 3.20 >$
 in 1977, $F^* = 2.57 >$ $F(0.95; 12,24) = 2.18$
 in 1976, $F^* = 2.19 >$
 in 1975, $F^* = 1.66 <$

d. conclusion: Effects exist.

9. Test for Equality of the Western and Middle Group Means at a traffic flow direction factor level, NS.

a. factor: geographic factor with factor levels W and Middle

b. stations observed: W -- 100-X and 256-A

Middle -- 254-B and 313-A

c. results: in 1978, $F^* = 6.25 >$

in 1977, $F^* = 1.26 <$

$$F(0.95; 12, 24) = 2.18$$

in 1976, $F^* = 4.22 >$

in 1975, $F^* = 4.35 >$

d. conclusion: Effects exist

e. remarks: This test and the previous one indicate that the middle stations and western or eastern stations are different in terms of monthly traffic volume variation pattern under the traffic flow direction, NS.

A summary of the above tests is shown below:

1. The traffic flow direction factor is the first one suggested for grouping in the FAP system.
2. No other factors are considered to have significant effects on monthly volume variation.

Interstate System

Three continuous count stations in this system are within the analysis. Their locations and other related information are indicated in Table 1 and Figure 1. Referring to the results of the two-factor model tests on the FAP data, we would suggest the traffic flow direction factor be the first one to be applied to the system. The only test to be performed using the single-factor model is to determine the existence of the traffic flow direction factor effects. The geographic factors cannot be tested because the three stations are located in the central part of the state.

Test for Equality of the North-South and East-West Traffic Flow
Direction Factor Level Means

a. factor: traffic flow direction factor with factor levels
NS and EW

b. stations observed: NS -- 172-A
EW -- 5474-A and 3070-A

c. results: in 1978, $F^* = 2.06 <$
in 1977, $F^* = 3.23 <$ $F(0.95; 12,12) = 2.69$
in 1976, $F^* = 10.85 >$
in 1975, $F^* = 3.91 >$

d. conclusion: Significant effects exist

A summary of the above test is that, as far as the limited data are concerned, the traffic flow direction factor is the first one suggested for grouping in the Interstate system.

Federal-Aid Secondary System

There are five continuous count stations available for the analysis in this system. Their locations and other related information are indicated in Table 1 and Figure 1. The following tests use the single-factor model.

1. Test for Equality of the North-South and East-West Traffic Flow Direction Factor Level Means.

a. factor: traffic flow direction factor with factor levels
NS & EW

b. stations observed: NS -- 42-A, 47-A and 200-X
EW -- 59-A and 5420-A

- c. results: in 1978, $F^* = 1.03 <$
in 1977, $F^* = 2.99 >$
in 1976, $F^* = 0.94 <$
in 1975, $F^* = 0.87 <$
 $F(0.95; 12, 36) = 2.04$
 - d. conclusion: 1977 data show the existence of effects;
1975, 1976, and 1978 do not.
 - e. remarks: Year 1977 was indicated to have extreme weather
conditions affecting traffic flow situations in January
and February, so the 1977 test result should not be
generalized to conclude the existence of effects is true
for the other years as well.
2. Test for Equality of the East and West Factor Level Means.
- a. factor: geographic factor with factor levels E & W
 - b. stations observed: E -- 47-A and 59-A
W -- 42-A and 5420-A
 - c. results: in 1978, $F^* = 0.69 <$
in 1977, $F^* = 0.17 <$
in 1976, $F^* = 1.10 <$
in 1975, $F^* = 1.49 <$
 $F(0.95; 12, 24) = 2.18$
 - d. conclusion: No effects exist
 - e. remarks: Another test for equality of the north and
south factor level means cannot be done because all the
stations in this system are located in the middle one-
third of the state.

A summary of the above tests is that not any factor can be a grouping factor for this highway category, as far as the data available are concerned.

The aforementioned factors detected for the FAP and Interstate highway system are not considered to have effects on monthly volume variation for the FAS system. This system serves intracounty travel, connecting nearby towns or cities. The travel distances are shorter and the travel generators connected have less significant activity systems than in the FAP and Interstate highway systems.

Grouping of Continuous Count Stations

The previous statistical analysis suggests a new grouping of the existing continuous count stations based on the difference of annual patterns of monthly adjustment factors. The data used were the four-year monthly adjustment factors from the existing continuous count stations.

Based on the statistical analysis of the existing ATR monthly volume variation information, the rural highway systems can be separated into eight groups, as shown below:

<u>Group No.</u>	<u>Proposed Classification Group</u>	<u>Continuous Count Stations</u>
	<u>Interstate</u>	
1	with North-South Traffic	172-A
2	with East-West Traffic	3070-A, 5474-A
	<u>Federal-Aid Primary</u>	
3	with North-South traffic in East	25-A, 301-A
4	with North-South traffic in Middle	254-B, 313-A
5	with North-South traffic in West	100-X, 256-A
6	with East-West traffic in East	68-A, 134-A, 279-A
7	with East-West traffic in West	262-A, 319-A
8	<u>Federal-Aid Secondary</u>	42-A, 47-A, 59-A 200-X, 5420-A
Total number of continuous count stations		19

The following procedures are based on this proposed group classification instead of the ISHC grouping to test whether the above grouping for the Interstate and Federal-Aid primary systems can improve the accuracy of AADT estimates and whether the number of the continuous count stations for each group can be reduced and still obtain the desired accuracy level.

Determination of Adequacy of the Continuous Count Station Programs

After grouping continuous count stations by numerical measures of the difference of monthly adjustment factors, it is desirable to know the accuracy levels of AADT estimates at coverage count stations for various groups of highway so as to evaluate and improve the existing counting operations, especially in the number and location of continuous count stations and the length and frequency of coverage counts.

The true error that can be expected in AADT estimates at coverage count stations can be measured by taking random samples of short duration counts (for example a 48 hour count as used by the ISHC) from the data at continuous count stations. Each sample is then expanded into an estimate of AADT by application of the appropriate group mean factor. At the continuous count stations the true AADT value is always known. The difference between the estimated and true AADT is termed estimated error.

It has been found that the standard deviations are significant measures of errors of AADT estimates that can be expected at coverage count stations (13). Since the continuous count stations, when grouped, are considered to represent the population of all the highway

sections of the groups, their standard deviation is also the measure of errors at the coverage count stations. The advantage of the standard deviation as a measure of errors is that it gives the size of error and also the expectation of how often an error of that size or smaller may occur. The formula of the standard deviation is as follows:

$$\text{Standard deviation} = \pm \sqrt{\frac{\sum E^2}{N-1}} \quad (5.2)$$

where N = number of random units in sample for a year

E = relative error of AADT estimate

$$\text{Relative error} = \frac{Y_1 - Y}{Y} \times 100 \quad (5.3)$$

where Y_1 = estimated AADT

Y = true AADT

Assuming a normal distribution of errors and a zero average error, approximately 68 percent of all errors can be expected to be within the range of plus and minus one standard deviation; 95 percent within two standard deviations. The "Guide" suggests ± 10 percent as an acceptable standard deviation limit for most uses of AADT information (14).

The standard deviation information can be utilized to check the adequacy of number and location of the existing ATR's in the groups having at least two ATR's. Unfortunately, the standard deviation is not available in the groups having less than two ATR's. In such a case there is a need to add control station(s) to make the standard deviation data available and, furthermore, to determine the desired number of stations.

For the groups having the standard deviations available, it is also desirable to know the confidence degree of the estimated standard deviations. The standard error is an indicator of the accuracy of these estimates when considering their values and the sample size from which they were computed.. If the range of plus and minus one standard error from the standard deviation is established about the estimated standard deviation, the fiducial probability is approximately 68 percent that the true standard deviation falls within this range; if the range of plus and minus two standard errors from the standard deviation is established, the fiducial probability is approximately 95 chances out of 100. The standard error of the standard deviation is also used to test for a significant difference between two standard deviations. The formula for the standard error of the standard deviation is as follows (15):

$$\text{Standard error of standard deviation} = \frac{\text{Est. Stand. Deviation}}{\sqrt{2N_1}} \quad (5.4)$$

Where N_1 = sample size used in estimating the standard deviation.

The following outline describes the steps used to produce simulated distributions of errors of estimated AADT which could be expected from 48-hour coverage count by applications of the ISHC group mean factors and the proposed group mean factors.

1. The definition of an ISHC group mean factor has been stated in Chapter II. The difference between the ISHC and the proposed group mean factors lies in the number of continuous count stations contributing to these two categories of means.

The different number of stations results from the suggested grouping procedure. To minimize the number of continuous count stations in a proposed group, a first trial, is made where two continuous count stations are randomly selected from the original stations in the proposed group of more than two stations for calculation of the proposed group mean factors. Then, by trial and error, the number of stations selected for determining the proposed group means may be increased one by one until the computed standard deviation is below 10 percent.

2. Coverage counts of 48-hour duration between Monday and Friday are simulated at continuous count stations. Since the number of continuous count stations is very limited, one count per station per month each year is needed to acquire a sufficient number of simulated counts.
3. The average weekday traffic of each sample coverage count is computed and expanded to an estimate of AADT by applying the aforementioned two kinds of group mean factors. Note that in the simulation we apply the group mean factors of a particular year to the average weekday traffic for that year, without updating the outdated traffic.
4. Each estimated AADT is compared to the true AADT for the particular continuous count stations and the plus or minus error of estimate as a percent of true AADT is computed by Formula (5.3).

5. The standard deviation of the resulting distribution of the directional percentage errors for each group in a year is computed by Formula (5.2).
- 6a. If all the original continuous count stations in a proposed group are involved in its mean factors in a particular trial, it is best to include the group mean factors used in the previous trial to expand the coverage counts taken at the remaining continuous count station. Among such special cases, if the number of the original continuous count stations are two, the monthly adjustment factors from one of the two stations are used to expand the coverage counts at the other station.
- b. Then, a temporary standard deviation results from Steps 4 and 5. It needs modifying by multiplying a constant. For example, for the groups having and requiring two stations, the modification constant is $\sqrt{1/2}$; for the groups having and requiring three stations, $\sqrt{2/3}$; for the groups having and requiring five stations, $\sqrt{4/5}$.
7. A four-year average standard deviation for each group is computed as an estimated standard deviation.
8. The standard errors of standard deviation are computed from Formula (5.4) with the average four-year standard deviation as a numerator and the number of the four-year sample counts as a denominator of the right side of this formula. If each year has the same number of sample counts, then $N_1 = 4 \times N$.
9. All the results of the above simulation steps are shown in Table 10.

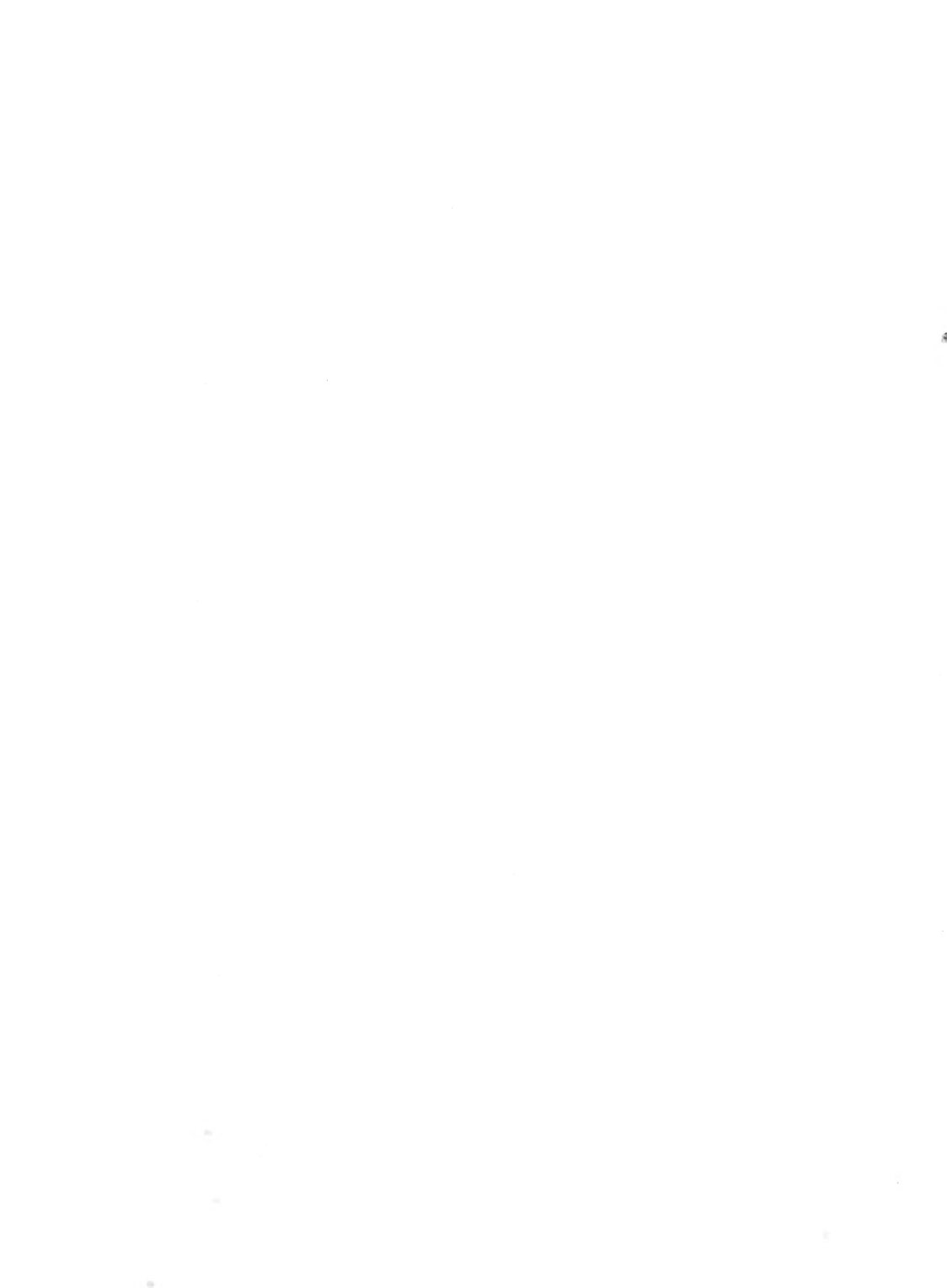


TABLE 10 : STANDARD DEVIATIONS OF PERCENT ERROR OF AADT ESTIMATED BY USE OF PROPOSED VS. ISHC GROUP MEAN FACTORS FOR RURAL GROUPS

NUMBER OF STATIONS SELECTED FOR PROPOSED GROUP MEAN	NUMBER OF STATIONS FOR ISHC GROUP MEAN	NUMBER OF COUNTS IN SAMPLE N (N1)	STANDARD DEVIATION IN PERCENT		
			PROPOSED GROUP MEAN FACTOR	ISHC GROUP MEAN FACTOR	COMPARISON AT = 0.25
GROUP NO. 1 -- Interstate N-S Traffic					
--	--	--	--	--	--
GROUP NO. 2 -- Interstate E-W Traffic					
2	3	12 (48)	8.36 (0.85)*	11.68 (1.19)*	GOOD
GROUP NO. 3 -- FAP, N-S Traffic in E					
2	12	12 (48)	8.05 (0.82)	9.28 (0.95)	FAIR
GROUP NO. 4 -- FAP, N-S Traffic in Middle					
2	12	12 (48)	7.99 (0.82)	8.91 (0.91)	FAIR
GROUP NO. 5 -- FAP, N-S Traffic in W					
2	12	12 (48)	8.00 (0.82)	11.65 (1.19)	GOOD
GROUP NO. 6 -- FAP, E-W Traffic in E					
2	12	12 (48)	11.65 (1.19)	13.89 (1.42)	GOOD
3	12	12 (48)	9.51 (0.97)	13.89 (1.42)	GOOD
GROUP NO. 7 -- FAP, E-W Traffic in W					
2	12	12 (48)	12.81 (1.31)	10.52 (1.07)	POOR
GROUP NO. 8 -- FAS					
2	6	36 (144)	11.23 (0.66)	8.30 (0.49)	POOR
3	6	24 (96)	12.01 (0.87)	9.70 (0.70)	POOR
4	6	12 (48)	9.71 (0.99)	7.28 (0.74)	POOR

NOTES :

* STANDARD ERROR OF STANDARD DEVIATION IN PERCENT

The simulated standard deviations, from the statistical point of view, result from:

1. The deviation of the monthly adjustment factor at an ATR from the group mean monthly adjustment factor; in other words, the degree of adequacy of the number and location of the existing continuous count stations.
2. The deviation of the average daily traffic of a two-weekday coverage count in a particular month from the monthly average weekday traffic at this coverage count station in the same month.

If the simulated standard deviation approximates the true standard deviation and the simulation results indicate a need for improvement in accuracy level, then reducing the deviation would result in higher degree of accuracy for the AADT estimates but would increase data gathering costs. A decision would have to be made as to a balance between increased costs and increased accuracy.

Table 10 indicates the following information:

1. For the proposed groups standard deviations resulting from the use of different numbers of stations for a group are provided to determine the desired number of stations for the group so as to provide a standard deviation of 10% or less.
2. The same sample counts are used for the ISHC groups as for the proposed groups so as to make a comparison in accuracy level between these two groupings.

3. A statistical comparison of standard deviations between the two categories of groupings is made using a level of significance α of 0.25, as a decision criterion. Then, "good" means that the standard deviation has been reduced with the use of the proposed group mean factors; "fair" means that the standard deviation is still the same; "poor" means that the standard deviation has been increased with the use of the proposed group mean factors. It should be noted that the relatively high α value of 0.25 has been chosen for this comparison simply because the number of the simulated continuous count stations is small and any difference between the two categories of standard deviations would not be likely to show up for small values of α (say, 0.05).

From Table 10, some conclusions can be made for the improved counting program:

1. For the Interstate system, the accuracy level is improved after the ATR's are grouped into two groups with different traffic flow directions. The standard deviation of the percent error of estimated AADT for the group of the east-west Interstate highways is below the desired limit of 10 percent. Accordingly, the original two stations in this group are considered to be adequate. Additional control stations are suggested for the group of the north-south Interstate system to obtain information on standard deviation, and then to determine the adequacy of number and location of the control stations. According to the experience with the

other groups, probably one additional continuous count station is needed for the required accuracy level. Seasonal control stations are required in some geographically representative locations to determine whether the monthly volume variation patterns in these locations are different. If there is such difference, more stations may be needed.

2. For the FAP system, four of the five groups show that the accuracy levels are improved after the ATR's were grouped into five groups and these levels are below 10 percent. Two stations each are required for Groups 3, 4, and 5, and three are required for Group 6. An additional station is needed for Group 7 to reduce the errors.

For the FAP system with east-west traffic, its grouping into Group No. 6 and Group No. 7 is weak according to Tests 4, 6 and 7 in the "Statistical Analysis of Traffic Volume Variation Information" section. These two groups can be arranged as a group. Analysis of its accuracy level, not shown in this table, suggests an additional station is still needed.

3. For the FAS system, four stations are sufficient for the desired accuracy, although the ISHC group, having six stations, has a lower error of AADT estimates. According to the statistical analysis, it is suggested to relocate Station 200-X to other groups which need a continuous count station.

Treatment of Suburban Road Sections

Introduction

The statistical analysis of the monthly adjustment factors for the grouping of continuous count stations and the estimation of the standard deviations of the errors of AADT estimates for the suburban roads are the same as for the rural highways. The state has four continuous count stations located in the suburban areas, from which the adjustment factors can be determined for the expansion of coverage counts taken in these areas.

Generally, the monthly variations of traffic volumes on suburban roads approach those of the roads in the cities (16). It has also been found that monthly traffic volume fluctuations in the cities are much smaller than they are on the rural roads, so the urban factors tend to approach unity for each month. This implies that the monthly variations in the suburban areas are usually smaller than those observed on the rural sections of the same route. An example is shown in Figure 2, which indicates the comparison of monthly adjustment factor variations over 12 months in 1976 between specific rural and suburban road sections of Route U.S. 31.

Therefore, expansion of traffic counts in the suburban developments of larger cities is specially treated in many states (17). The ISHC has assigned suburban road sections within the boundaries of urban areas as defined by the FHWA to the Urban Routes group, including an ATR in the downtown area of a particular urban area. Only the four stations not in downtown areas are involved in the Suburban Routes group study.

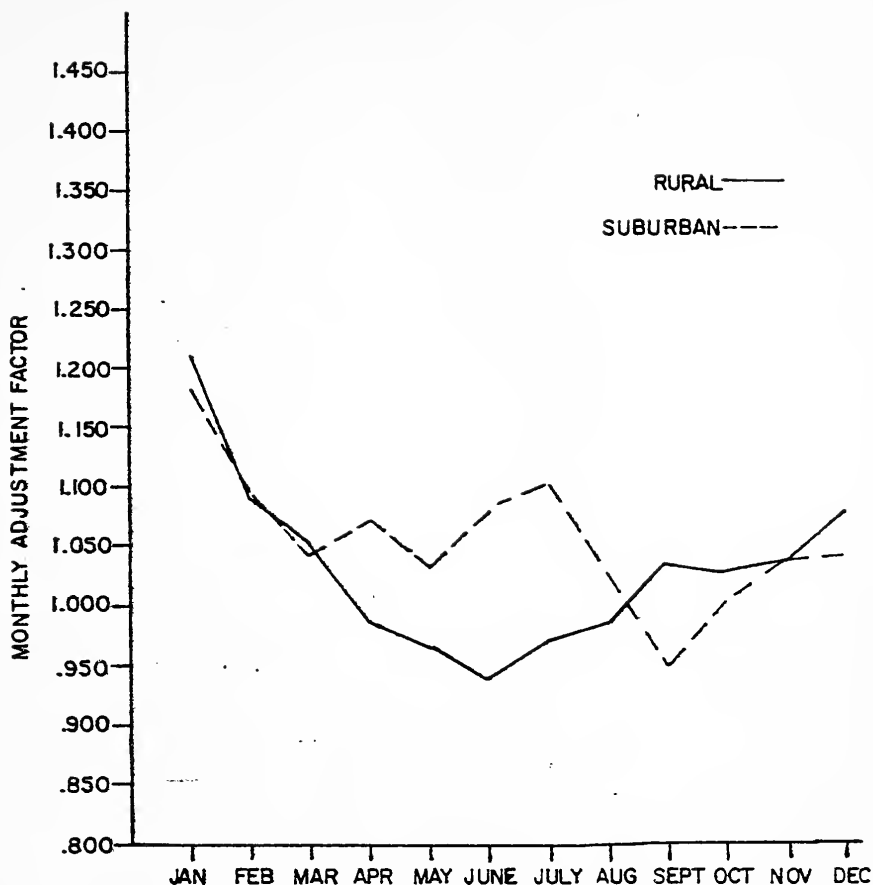


FIGURE 2. COMPARISON OF MONTHLY VARIATIONS IN
TRAFFIC VOLUME BETWEEN RURAL AND
SUBURBAN SECTIONS ON ROUTE U.S. 31
FOR 1976

The adequacy of the existing continuous count station program is evaluated and then determination of the desired number of continuous count stations at the aforementioned accuracy level is made.

Statistical Analysis of Traffic Volume Variation Information

There are four continuous count stations in the group of suburban routes. Their locations and other related information are indicated in Table 1 and Figure 1. The usual practice for grouping ATR's on urban/suburban roads in other states is to divide them into two groups, large urban areas and small urban areas, according to urban area size. The former type of urban areas has the population not less than 50,000 while the latter one has the population less than 50,000. This factor and the aforementioned factors for the rural highways are all tested to determine their effects on traffic volume variations on the suburban roads. Unfortunately, the traffic flow direction for the four stations are all north-south. It is therefore not possible to group the stations on the basis of traffic flow direction. The following tests use the single-factor ANOVA model.

1. Test for Equality of the Two Factor Level Means for Large Urban Area Suburban Roads and Small Urban Area Suburban Roads.
 - a. factor: urban area type factor with factor levels

Large Urban and Small Urban Areas
 - b. stations observed: Large Urban -- 40-A and 45-B

Small Urban -- 72-A and 73-A

- c. results: in 1978, $F^* = 4.62 >$ $F(0.95; 12,12) = 2.69$
in 1975, $F^* = 1.25 <$ (Station 72-A not included in 1978 and 1975 data)
in 1977, $F^* = 2.26 >$
in 1976, $F^* = 0.50 <$ $F(0.95; 12,24) = 2.18$
in 1974, $F^* = 0.37 <$
- d. conclusion: 1978 and 1977 data show the existence of effects
- e. remarks: The final conclusion is difficult to make, since the two years showing the existence of effects had extreme weather conditions. Additional data in 1974 are needed to see whether it is necessary to subdivide the group into different urban area type subgroups. It seems more convincing to treat all the ATR's in the suburban group as one group. However, grouping or not will be tested to see which has better results.
- f. notes: Station 72-A showed abnormal monthly volume variation data in 1978 and 1975 due to road construction and closing respectively, so only one station was observed in the group of small urban areas for the two years.
2. Test for Equality of the East and West Factor Level Means.
- a. factor: geographic factor with factor levels E & W.
- b. stations observed: E -- 45-B
W -- 40-A and 73-A

c. results: in 1978, $F^* = 0.59 <$
 in 1977, $F^* = 0.33 <$ $F(0.95; 12,12) = 2.69$
 in 1976, $F^* = 0.60 <$
 in 1975, $F^* = 0.52 <$

d. conclusion: No effects exist

3. Test for Equality of the Western and Middle Group Means.

a. factor: geographic factor with factor levels W and Middle

b. stations observed: W -- 40-A and 73-A

Middle -- 72-A

c. results: in 1977, $F^* = 0.43 <$ $F(0.95; 12,12) = 2.69$
 in 1976, $F^* = 1.77 <$

d. conclusion: No effects exist

e. remarks: This geographic factor cannot be said to affect
 the traffic volume variation pattern on the suburban
 roads.

A summary of the above tests is that, as far as the available data are concerned, the traffic volume variation patterns are statistically the same throughout the geographic areas of the state.

For the determination of existence of effects of the traffic flow direction factor, Station 2262-A, with east-west traffic flow direction, must be observed together with the four stations on the suburban roads with north-south traffic flow direction to perform this desired test. This test, not shown here, has indicated that the traffic flow direction factor does not cause effects on the monthly traffic volume variation pattern on the suburban roads. If there were such effects, it would not be assured that these effects were caused by the traffic

flow direction factor because the geographic difference between cities and suburban areas probably contributed to the effects. So, it can be concluded that the traffic flow direction factor would not be a grouping factor for the Suburban Routes group, as was the case with the geographic factors.

Determination of Adequacy of the Suburban Continuous Count Station Program

From the previous statistical analysis, it appears to be best not to subdivide the four continuous count stations on the suburban roads into more than one group. However, the subdivision of this group into two subgroups by urban area type factor will be tested. Tests will also be made to determine the desired number of continuous count stations. For this group, the four stations are indicated below:

<u>Group No.</u>	<u>Proposed Classification Group</u>	<u>Continuous Count Stations</u>
9	Suburban Routes	40-A, 45-B, 72-A, 73-A

Tables 11 and 12 indicate the standard deviations of AADT estimates in the proposed and existing ISHC counting programs respectively for a single suburban group and for two groups (with grouping by urban area type factor). The results are summarized as follows:

1. From Table 11, only two stations are needed for the Suburban Routes group to satisfy the desired standard deviation, so the other two stations could be relocated or eliminated. According to our statistical analysis, the two extra stations are 45-B and 72-A.

TABLE 11 : STANDARD DEVIATIONS OF PERCENT ERROR OF AADT ESTIMATED BY USE OF PROPOSED VS. ISHC GROUP MEAN FACTORS FOR A SINGLE SUBURBAN GROUP

NUMBER OF STATIONS SELECTED FOR PROPOSED GROUP MEAN	NUMBER OF STATIONS FOR ISHC GROUP MEAN	NUMBER OF COUNTS IN SAMPLE N (N1)	STANDARD DEVIATION IN PERCENT		
			PROPOSED GROUP MEAN FACTOR	ISHC GROUP MEAN FACTOR	COMPARISON AT = 0.25
2	5	24 (72)	8.75 (0.73)*	7.96 (0.66)*	FAIR

NOTES :

* STANDARD ERROR OF STANDARD DEVIATION IN PERCENT

TABLE 12 : STANDARD DEVIATIONS OF PERCENT ERROR OF AADT ESTIMATED BY USE OF PROPOSED VS. ISHC GROUP MEAN FACTORS FOR TWO SUBURBAN GROUPS

NUMBER OF STATIONS SELECTED FOR PROPOSED GROUP MEAN	NUMBER OF STATIONS FOR ISHC GROUP MEAN	NUMBER OF COUNTS IN SAMPLE N (N1)	STANDARD DEVIATION IN PERCENT		
			PROPOSED GROUP MEAN FACTOR	ISHC GROUP MEAN FACTOR	COMPARISON AT = 0.25
GROUP — LARGE URBAN AREA SUBURBAN ROADS					
2	5	12 (48)	7.92 (0.81)*	7.55 (0.77)*	FAIR
GROUP — SMALL URBAN AREA SUBURBAN ROADS					
2	5	12 (24)	6.98 (1.01)	10.46 (1.51)	GOOD

NOTES :

* STANDARD ERROR OF STANDARD DEVIATION IN PERCENT

2. From Table 12, the original four stations are needed for the two suburban subgroups to achieve the same accuracy level.
3. The standard deviations using the two groups and the single proposed group are statistically the same, but the use of the latter group is more economical because the number of stations required is less than that required by the two groups arrangement.

Therefore, it is not suggested to further group the suburban routes into the suburban roads in urbanized areas and in small urban areas. This means that all the suburban routes would be treated as one group for estimating AADT volumes. Thus, it is recommended that only two continuous count stations are needed for the Suburban Routes group.

Treatment of Special Traffic Routes

After the identification of the routes with special traffic volume variation patterns in Appendix D, it is desired to apply appropriate monthly adjustment factors to the coverage counts taken on these routes.

The road sections exhibiting unusual patterns of monthly variations of traffic volume are limited in extent, about 10 percent of the state highway system in terms of number of road sections or highway mileage. According to the "Guide", a single continuous or suitable seasonal control station is ordinarily sufficient to obtain the necessary adjustment factors for such sections. It has been observed that two continuous count stations are located on coal haul routes and one is located in a summer recreation route. These three stations are indicated below:

<u>Group No.</u>	<u>Proposed Classification Group</u>	<u>Continuous Count Station</u>
10	Coal Traffic Routes	74-A, 173-A
11	Summer Recreation Routes	281-A

The major goal of the proposed counting program for these groups is to retain only one continuous count station for each of them, as per the "Guide" (18). So, one of the two stations on the coal traffic routes should be relocated to other places where there is a need for continuous count stations, or else it could be eliminated.

Recommendations for the Statewide Vehicle Counting

Continuous Count Station Program

The goal of the continuous counting program is to provide a series of adjustment factors to allow expansion of short-term (48-hour coverage) counts. A successful expansion of the coverage counts is a pivotal part of the whole counting program. To achieve this goal, the proposed continuous count station program has the following objectives:

1. to secure a balanced representation of the various functional classifications of highway sections. The three functional classifications for the rural highways presently used by the ISHC were verified to be adequate for representing the diversified traffic volume variation patterns on the state highway system. These three functional classes are Interstate, arterial and major collector.
2. to provide a reasonable representation of significant traffic flow characteristics. Traffic flow direction has been found to influence the monthly traffic volume variation on the two

higher classes of rural highways. Two such traffic flow directions are north-south traffic flow and east-west traffic flow.

3. to provide a geographic representation within functional classes. The east and west of the state indicate different traffic volume variation patterns.
4. to retain existing station location were possible. The purposes of retaining existing station locations is three-fold. First, to provide for analysis of historical trends; second, to provide for evaluation of the existing and proposed counting program; third, to reduce the costs of establishing new locations, because all the stations have operating loops.

These objectives are achieved by the proposed continuous count program at the desired accuracy level of AADT estimates. The proposed continuous count station program will provide balanced, representative counts while minimizing the cost of locating new stations.

The number of continuous count stations in the proposed counting program is two less than the present program. The other change lies in the balance of the proposed plan, providing a wide range of representative statistically classified stations. The existing ISHC counting program contains six groups (including two special station groups) while the proposed one contains ten groups. A comparison of the proposed versus the ISHC station distribution among the proposed groups appears in Table 13. Note that two stations from the four redundant stations on the FAS, suburban and coal traffic roads have been relocated

Table 13. Proposed vs. ISHC Group Distribution of the Continuous Count Stations

High Volume Roads in Rural and Suburban Areas (> or = 500 AADT)		
Proposed Group	Proposed No. of Stations	ISHC No. of Stations
Interstate		
With North-South Traffic	2	1
With East-West Traffic	2	2
Federal-Aid Primary		
With North-South Traffic in the East	2	2
With North-South Traffic in the Middle	2	2
With North-South Traffic in the West	2	2
With East-West Traffic	6	5
Federal-Aid Secondary	4	5
Suburban Routes	2	4
Coal Traffic Routes	1	2
Summer Recreation Routes	1	1
TOTAL	24	26
Low Volume Roads (< 500 AADT)	---*	1
Urban Routes	---*	1

Notes:

*Not within this research study.

respectively to the groups of the north-south Interstate highways and the east-west FAP highways. The exact locations for the two relocated stations should be determined by the ISHC counting personnel to provide locations which are stable and representative over time and space. For the other two stations, it is suggested to relocate them to low volume roads, city streets or rural highways where the data from seasonal control stations indicate a need for new continuous count stations.

The method presently used by the ISHC for computing monthly adjustment factors which is the ratio of AADT to the four-weekday monthly average weekday traffic is recommended for use in the proposed counting program. This is because, as a rule, the variation of Friday volumes within a month is greater than that of the other weekdays, and thus AADT estimates based on 5-weekday counts tend to be less accurate than those based on 4 weekdays. So, the 48-hour coverage counts should be taken between Monday and Thursday, not between Monday and Friday.

The group mean monthly adjustment factors are computed for each proposed group to apply to the coverage counts in the same group. The difference between the proposed and ISHC computation methods is that the ISHC group mean factors are computed from the monthly factors which do not exceed the maximum range of 0.20 for each of the ISHC groups while the proposed group mean factors are computed without consideration of this range.

Seasonal Control Count Station Program

The ISHC has started developing a seasonal control station system around the functional classification to identify particular problem areas, that is, areas with special seasonal patterns.

First, like other states, Indiana has not enough information for assigning the road sections to pattern groups which cannot be grouped by the existing continuous count stations, such as the Interstate Highways in some geographic areas and other road sections where the changes in the group patterns are not easily ascertained. In such situations, it is desirable to establish additional control stations to define the seasonal volume variation patterns. If the seasonal patterns are available, it can be determined how many subgroups and how many additional continuous count stations are needed for the Interstate system and FAS system.

Secondly, the seasonal control stations could be used to acquire the data on errors of AADT estimates in the groups where there are not enough continuous count stations for estimating standard deviations.

The method for selecting a location for a seasonal control station in a group is suggested to be the same as that for selecting a continuous count station location.

In general, the location of the stations of the seasonal control network supplement the locations of the continuous count network for the data base required to estimate the AADT volumes. At the time the continuous count network becomes sufficiently representative of the full range of travel characteristics and all the road sections have been grouped, the number of seasonal control stations can be significantly reduced.

Coverage Count Station Program

As previously discussed, the goal of the proposed traffic counting program is to provide reliable statewide AADT estimates. Besides a

good continuous count station program, an efficient coverage counting program is also required.

First of all, all road sections should be placed in the proper group based on the characteristics of the road section. In the state, the assignment of the road sections to the two "Special Station" groups is not presently done. In this research the coal traffic routes and recreational traffic routes have been identified, and should be reviewed by the ISHC personnel. Then, the proper group (mean) factors can be applied to the coverage counts taken on these routes.

Secondly, the frequency of the coverage counts might be modified. Since the previous simulation is based on the use of the current coverage counts, probably more errors would have been found in AADT estimates expanded from outdated coverage counts. In the state, the coverage counting program involves different year cycles depending on the traffic growth rate of an area. On the average, it is made in a five year cycle; that is, about one-fifth of the coverage counts are made each year. Outdated coverage counts, after application of the contemporary group mean factors, are updated to the current year by an estimated growth rate. So, a large cycle would probably cause unrealistic values for the updated estimates of AADT volumes. A maximum cycle of three years is recommended by the FHWA.

If more accurate AADT estimates are desirable or if the present number of continuous count stations should be significantly reduced the length of the coverage counts could be extended. Theoretically, if the presently used 48-hour duration is lengthened to four

consecutive weekdays from Monday to Thursday the standard deviation of the AADT estimates will be reduced by a ratio of $\sqrt{2}$. Although, in fact, it cannot be reduced as much, considerable reduction of errors is possible, however the cost of obtaining the data would be increased significantly.

Estimation of Benefits of the Improved Methods

The recommended statewide vehicle counting program is considered to be a cost effective program for the rural and suburban highways. Most standard deviations of the percent error of AADT estimates are reduced after grouping for the Interstate and FAP systems, and the number of continuous count stations is reduced from 9 to 6 by statistical techniques for the FAS system and suburban routes (Table 13). On the average, the standard deviation for all of the highway systems is reduced from the present 9 percent to 8 percent, assuming the coverage counts to be applied are all current counts. These two figures are computed by averaging the standard deviations of all the proposed groups for each of the two categories of group mean factors as shown in Tables 10 and 11. This small reduction, one percent, is due to the redistribution of the errors among groups after grouping.

The other states such as those observed in this research have many more continuous count stations than this state to obtain their desired accuracy levels, usually the standard deviation of 10 percent for the errors of AADT estimates.

CHAPTER VI

CONCLUSIONS

Summary

The review and analysis of existing statewide vehicle counting programs in several states served as background for the recommendations made in this research for improved methods for the Indiana Statewide vehicle counting program.

The proposed grouping of road sections should improve the accuracy of AADT estimates at reduced cost for continuous count stations. The new grouping of existing continuous count stations has resulted in more groups than the present ISHC grouping. The number of continuous count stations for each group is based on statistical analysis of simulated data from the existing continuous count stations. For the six proposed groups established for the Interstate and FAP systems, accuracy levels of AADT estimates are increased to the desired level of $\pm 10\%$, but the total number of continuous count stations is also increased from 14 to 16. For the FAS system and suburban routes, the number of the total continuous count stations is decreased from 9 to 6 and the accuracy level is maintained within $\pm 10\%$, the desired level. For the two special types of routes, only one continuous count station is needed for each.

Other suggestions for the improved method include the establishment of a seasonal control station network and the shortening of the coverage count cycle. These actions are encouraged to help raise the accuracy level of estimating AADT volumes of road sections.

Recommended Statewide Vehicle Counting Program for Indiana

Summarized below are the recommendations for an improved statewide vehicle counting program for the State of Indiana.

The highway system is divided into different categories as to area type (rural, suburban, and urban), AADT volume (higher and lower than 500 AADT), and traffic pattern (general and special). Only rural and suburban roads with AADT volumes greater than 500 are included within the recommendations of this research.

Continuous Count Station Program

The proposed continuous count station program suggested in Table 14 below provides statistically based counts representative of the statewide traffic volume pattern while requiring fewer continuous count stations than are now used.

For each proposed group the group mean monthly adjustment factor is computed by averaging all the monthly adjustment factors for a particular month. The 0.20 rule suggested in the FHWA "Guide for Traffic Volume Counting Manual" is not used in this computation.

Seasonal Control Count Station Program

The function of the proposed seasonal control station program is to supplement the locations of the continuous count network for the data base required to obtain seasonal factors and factor groups. A seasonal control station program is needed to provide seasonal volume variation information in areas where no continuous count stations are provided. A long range goal is to reduce the number of seasonal control stations to a small number when the continuous count station program

Table 14. Proposed Continuous Count Station Program

Group	Station Numbers
Group No. 1 -- Interstate, N-S Traffic	172-A*
Group No. 2 -- Interstate, E-W Traffic	3070-A, 5474-A
Group No. 3 -- FAP, N-S Traffic in East	25-A, 301-A
Group No. 4 -- FAP, N-S Traffic in Middle	254-B, 313-A
Group No. 5 -- FAP, N-S Traffic in West	100-X, 256-A
Group No. 6 -- FAP, E-W Traffic	68-A, 134-A, 279-A, 262-A, 319-A*
Group No. 7 -- FAS	42-A, 47-A, 59-A, 5420-A
Group No. 8 -- Suburban Routes	40-A, 73-A
Group No. 9 -- Coal Traffic Routes	Either 74-A or 173-A
Group No. 10 -- Summer Recreation Routes	281-A
Total Number of Continuous Count Stations: 24	

Notes:

*An additional continuous count station is required.

becomes sufficiently representative of the full range of travel characteristics and all road sections are properly grouped.

Recommendations are to locate eight seasonal control stations on the Interstate system. One station is to be located in each of the northeast, northwest, southeast and southwest quarters of the state for both the North-South and East-West Interstates. It is also desirable to establish additional seasonal control stations to help assign certain road sections to groups where such assignment is not easily seen by examination of the section's characteristics.

It is recommended that seasonal control counts be taken for a full week each month per year. If stations are counted less frequently than once each month then it may be difficult to assign road sections to groups.

Coverage Count Station Program

The proposed coverage count station program is to help the control station programs in providing reliable statewide AADT estimates at coverage count stations.

All road sections are recommended to be placed in the proper group established in the control station programs based on the characteristics of the road sections. Thus, the proper group mean factors can be applied to the coverage counts in that group.

The accuracy levels of AADT estimates at coverage count stations can be raised by extending the length of the coverage counts. If additional accuracy level is desirable considering the additional cost involved, the counting duration at coverage count stations may be extended from the existing 48 hours to four consecutive weekdays from Monday to Thursday as suggested in the FHWA "Guide".

It is recommended by the FHWA that the frequency of coverage counting be reduced from the existing 5-year cycle to a 3-year cycle if additional accuracy level is desirable. Axle correction factors derived from vehicle classification counts are recommended to be used together with monthly adjustment factors to correct tube-type machine counts.

Recommendations for Further Studies

Based on experience gained in this analysis, recommendations for further research study are concerned with urban counting, VMT estimating and vehicle classification counting.

1. In Indiana no urban counting program is undertaken by the ISHC. It is suggested that a statewide urban counting program be established based on statistical analysis and evaluation.
2. VMT is important for the development of highway financing and taxation schedules, the appraisal of safety programs, and as a measure of the service provided by highway transportation. The application of statistical methods to its estimating procedure is suggested.
3. Vehicle classification counts, like AADT and VMT, are indispensable for highway planning, design and operations. Besides, they provide the axle correction factors for road-tube type counts. A review and evaluation of the existing vehicle classification count program are desired to meet the overall counting needs in the State.

FOOTNOTES

FOOTNOTES

- ¹B. B. Petroff, "Experience in Application of Statistical Method to Traffic Counting". Public Roads, December 1956, p. 113.
- ²C. Jencks, "Review of the Indiana State Highway Commission Traffic Counting Program". Unpublished Report, Federal Highway Administration: Indianapolis, Indiana, July 1978.
- ³Federal Highway Administration, Guide for Traffic Volume Counting Manual, U.S. Department of Transportation, March 1970, p. 5-8.
- ⁴C. Jencks, "Review of the Indiana State Highway Commission Traffic Counting Program". Unpublished Report, Federal Highway Administration: Indianapolis, Indiana, July 1978.
- ⁵Federal Highway Administration, Guide for Traffic Volume Counting Manual, U.S. Department of Transportation, March 1970, p. 6-8.
- ⁶Federal Highway Administration, Highway Planning Program Manual, Vol. 4: Traffic, Chapter I: Volume Counts, U.S. Department of Transportation, March 1970, p. 4.
- ⁷Federal Highway Administration, National Functional System Mileage and Travel Summary: 1976 National Highway Inventory and Performance Study, U.S. Department of Transportation, June 1977.
- ⁸C. Jencks, "Review of the Indiana State Highway Commission Traffic Counting Program". Unpublished Report, Federal Highway Administration: Indianapolis, Indiana, July 1978.
- ⁹Federal Highway Administration, Guide for Traffic Volume Counting Manual, U.S. Department of Transportation, March 1970, pp. 11-15.
- ¹⁰Ibid., pp. 4-13.
- ¹¹Ibid., pp. 6-11.

- ¹²B. B. Petroff, "Experience in Application of Statistical Method to Traffic Counting". Public Roads, December 1956, p. 115.
- ¹³B. B. Petroff, "Experience in Application of Statistical Method to Traffic Counting". Public Roads, December 1956, p. 114.
- ¹⁴Federal Highway Administration, Guide for Traffic Volume Counting Manual, U.S. Department of Transportation, March 1970, p. 5.
- ¹⁵R. L. Drush, "Estimating Annual Average Daily Traffic from Short Term Traffic Counts". HRB Record 118, 1966, p. 92.
- ¹⁶Federal Highway Administration, Guide for Traffic Volume Counting Manual, U.S. Department of Transportation, March 1970, p. 22.
- ¹⁷B. B. Petroff, "Experience in Application of Statistical Method to Traffic Counting". Public Roads, December 1956, p. 113.
- ¹⁸Federal Highway Administration, Guide for Traffic Volume Counting Manual, U.S. Department of Transportation, March 1970, p. 13.
- ¹⁹Indiana State Highway Commission, Highway Planning and Research: Fiscal 1979 Work Program and Cost Estimate, Project HPR-PL-1(16), Indianapolis, Indiana, p. 4.
- ²⁰T. W. Schulenberg, "Highway Needs Analysis in Energy Production Regions of Indiana - Coal". Original report for a Federal Highway Administration Nationwide Project in Progress, Indiana State Highway Commission, Indiana, undated, p. 1.
- ²¹Ibid.
- ²²Ibid., p. 4.
- ²³Ibid., p. 12a.
- ²⁴Lincoln Heritage Trail Map.

BIBLIOGRAPHY

BIBLIOGRAPHY

1. Anderson, V. L. and McLean, R. R., Design of Experiments: A Realistic Approach. Marcel Dekker, Inc.: New York, 1974, pp. 1-25.
2. Box, P. C. and Oppenlander, J. C., Manual of Traffic Engineering Studies. Institute of Transportation Engineers, 1976, pp. 3-42.
3. Institute of Transportation Engineers, Transportation and Traffic Engineering Handbook. 23 Chapters. Prentice-Hall, Inc.: Englewood Cliffs, New Jersey, 1976. Chapter 10: Traffic Studies, by D. E. Cleveland, pp. 410-417.
4. Colorado State Department of Highways, "Summary of Colorado's Traffic Counting Program". Denver, Colorado, undated.
5. Deig, D., "Functional Classification". Engineering Extension Series No. 148, Proceedings of the 63rd Annual Road School, March 1977, pp. 169-180.
6. Drush, R. L., "Estimating Annual Average Daily Traffic from Short Term Traffic Counts". HRB Record 118, 1966, pp. 85-95.
7. Federal Highway Administration, 1968 National Highway Functional Classification Study Manual, U.S. Department of Transportation, April 1969.
8. Federal Highway Administration, Guide for Traffic Volume Counting Manual, U.S. Department of Transportation, March 1970.
9. Federal Highway Administration, Guide to Urban Traffic Volume Counting, U.S. Department of Transportation, October 1975.
10. Federal Highway Administration, Highway Functional Classification: Concepts, Criteria and Procedures, U.S. Department of Transportation, July 1974.
11. Federal Highway Administration, Highway Planning Program Manual, Vol. 4: Traffic, Chapter I: Volume Counts, U.S. Department of Transportation, July 1973.
12. Federal Highway Administration, National Functional System Mileage and Travel Summary: 1976 National Highway Inventory and Performance Study, U.S. Department of Transportation, June 1977.

13. Florida Department of Transportation, "P.E. and Engineering Training Manual: Traffic Counts Subunit". Tallahassee, undated.
14. Georgia Department of Transportation, "State of Georgia Traffic Counting Program". Atlanta, Georgia, April 1978.
15. Hobbs, F. D., Traffic Planning and Engineering, Pergamon Press: New York, 1974, pp. 52-62.
16. Illinois Department of Transportation, "Traffic Count Policy and Work Standards". Springfield, Illinois, September 1974.
17. Indiana State Highway Commission, Highway Planning and Research: Fiscal 1979 Work Program and Cost Estimate, Project HPR-PL-1(16), Indianapolis, Indiana, pp. 1-87.
18. ITE Committee 6-1, "Estimating ADT on Low-Volume Roads (<2000 VPD)". Traffic Engineering, Vol. 44, No. 13, October 1974, pp. 19-22.
19. Jencks, C., "Review of the Indiana State Highway Commission Traffic Counting Program". Unpublished Report, Federal Highway Administration: Indianapolis, Indiana, July 1978.
20. Kunzman, W. A., "A Simplified Procedure to Determine Factors for Converting Volume Counts to ADT's". Traffic Engineering, October 1976, pp. 28-30.
21. Lincoln Heritage Trail Foundation, Lincoln Heritage Trail Map - States of Kentucky, Indiana and Illinois, Champaign, Illinois, undated.
22. Monahan, M. J., "Traffic Volume Counting - FHWA Review". Letter dated July 14, 1978, Federal Highway Administration: Indianapolis Indiana.
23. Michigan Department of State Highways and Transportation, Michigan Traffic Data from Automatic Traffic Recorder Stations June 1978, Lansing, Michigan, undated.
24. Michigan Department of State Highways and Transportation, "Summary of Michigan's County Policy". Letter dated September 1978, Lansing, Michigan.
25. Minnesota Department of Transportation, 1977 Automatic Traffic Recorder Data Summary, St. Paul, Minnesota, undated.
26. Minnesota Department of Transportation, "Summary of Minnesota's Count Policy". Letter dated August 1978, St. Paul, Minnesota.
27. Musleh, F. E., "Indiana Highway Needs 1976-1995". Engineering Extension Series No. 148, Proceedings of the 63rd Annual Road School, March 1977, pp. 90-105.

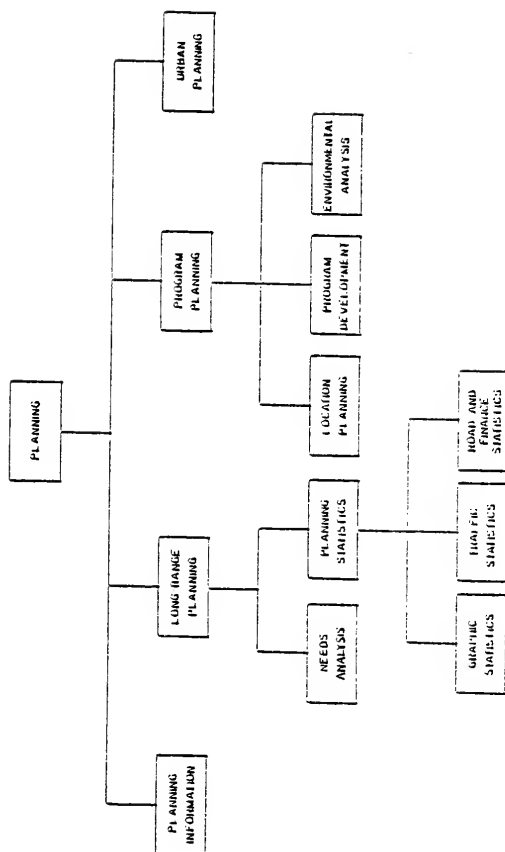
28. Neter, J. and Wasserman, W., Applied Linear Statistical Models: Regression, Analysis of Variance and Experimental Design, Richard D. Irwin, Inc.: Homewood, Illinois, 1974, pp. 419-603.
29. New Mexico State Highway Department, "NCHRP Project 8-20 Questionnaire on State Vehicle Counting Programs". In cooperation with National Research Council, Santa Fe, New Mexico, undated.
30. New Mexico State Highway Department, New Mexico Traffic Survey 1977, Santa Fe, New Mexico, undated.
31. New York Department of Transportation, "Coverage Count Factoring Procedure". Albany, New York, undated.
32. New York Department of Transportation, NYSDOT Traffic Count Program Report, Albany, New York, November 1977.
33. Oregon Department of Transportation, "Traffic Counting". Salem, Oregon, undated.
34. Oregon Department of Transportation, Traffic Volume Tables for 1977, Salem, Oregon, July 1978.
35. Petroff, B. B., "Experience in Application of Statistical Method to Traffic Counting". Public Roads, December 1956, pp. 110-117.
36. Petroff, B. B., "Some Criteria for Scheduling Mechanical Traffic Counts". HRB Proceedings, Vol. 26, 1946, pp. 389-396.
37. Petroff, B. B. and Blensly, R. C., "Improving Traffic-Count Procedures by Application of Statistical Method". HRB Proceedings 33, 1954, pp. 362-375.
38. Rhode Island Department of Transportation, "Traffic Count Program: Volume I and Volume II". Providence, Rhode Island, April 1977.
39. Russell, E. R., and Hittle, J. E., "Guidelines for Traffic Counts on County Roads". County Highway Series No. 12, Purdue University-Engineering Experiment Station: Lafayette, Indiana, June 1971.
40. Schulenberg, T. W., "Highway Needs Analysis in Energy Production Regions of Indiana - Coal". Original Report for a Federal Highway Administration Nationwide Project in progress, Indiana State Highway Commission, Indiana, undated.
41. Schulenberg, T. W., "Senate Concurrent Resolution #21: George Rogers Clark Memorial Highway". Letter dated May 23, 1974, Indiana State Highway Commission, Indiana.
42. Utah Department of Transportation, Traffic Bulletin, Salt Lake City, Utah, July 1978.

43. Utah Department of Transportation, "Traffic Volume Count Flow Charts". Salt Lake City, Utah, undated.
44. Utah Department of Transportation, Traffic on Utah Highways 1977, Salt Lake City, Utah, June 1978.
45. Vodrazka, W. C. and Michael, H. L., "Annual Travel on County Highways of Indiana". County Highway Series No. 9, Purdue University - Engineering Experiment Station: Lafayette, Indiana, March 1967.
46. Wisconsin Department of Transportation, "Summary of Count Policy". Letter dated September 1978, Madison, Wisconsin.
47. Woods, K. B., Highway Engineering Handbook, 4 Parts, McGraw-Hill Book Company, Inc.: New York, 1960, Part 1, Section 2: Highway Planning, by H. L. Michael, pp. 4-16.

APPENDICES

APPENDIX A

Organizational Chart of the ISHC Division of Planning



Source: Footnote No. 19.

APPENDIX B

Mileage of 1980 Functional Systems by Jurisdiction in Indiana

TABLE B.1 : 1980 FUNCTIONAL SYSTEM MILEAGE BY JURISDICTION -- RURAL

FUNCTIONAL SYSTEM	STATE	FEDERAL DOMAIN	OTHER	TOTAL
INTERSTATE	874	0	0	874
OTHER PRINCIPAL ARTERIAL	1,188	0	0	1,188
MINOR ARTERIAL	3,120	0	0	3,120
ARTERIAL TOTAL	5,182	0	0	5,182
MAJOR COLLECTOR	4,504	0	4,237	8,741
MINOR COLLECTOR	23	0	11,311	11,334
COLLECTOR TOTAL	4,527	0	15,548	20,075
LOCAL	12	0	48,847	48,859
TOTAL	9,721	0	64,395	74,116

Source: Footnote No. 7.

TABLE B.2 : 1980 FUNCTIONAL SYSTEM MILEAGE BY JURISDICTION -- URBAN

AREA TYPE		SMALL URBAN			URBANIZED			
FUNCTIONAL SYSTEM	STATE	FEDERAL DOMAIN	OTHER	TOTAL	STATE	FEDERAL DOMAIN	OTHER	TOTAL
INTERSTATE	27	0	0	27	232	0	0	232
OTHER FREEWAYS AND EXPRESSWAYS	59	0	0	59	76	0	22	98
OTHER PRINCIPAL ARTERIAL	465	0	56	521	538	0	280	818
MINOR ARTERIAL	110	0	644	754	86	0	1,487	1,573
ARTERIAL TOTAL	661	0	700	1,361	932	0	1,789	2,721
COLLECTOR	0	0	633	633	3	0	1,195	1,198
LOCAL	1	0	4,017	4,018	5	0	7,670	7,675
TOTAL	662	0	5,350	6,012	940	0	10,654	11,594

Source: Footnote No. 7.

APPENDIX C

Mileage of 1976 Realigned Federal-Aid Highway Systems in Indiana

TABLE C.1 : MILEAGE OF REALIGNED FEDERAL-AID HIGHWAY SYSTEMS OF INDIANA (AS OF DECEMBER 31, 1976)

NATIONAL SYSTEM OF DEFENSE AND INTERSTATE HIGHWAYS		FEDERAL-AID PRIMARY HIGHWAY SYSTEM		FEDERAL-AID URBAN HIGHWAY SYSTEM		FEDERAL-AID SECONDARY HIGHWAY SYSTEM		GRAND TOTAL FEDERAL-AID HIGHWAY SYSTEMS	
RURAL	URBAN	TOTAL	RURAL	URBAN	TOTAL	URBAN	RURAL	URBAN	TOTAL
887	247	1,134	4,312	663	4,975	4,738	8,561	13,760	19,408

Source: Footnote No. 7.

APPENDIX D

Special Traffic Routes Study

General Description

After the ISHC completed the grouping procedures, the ungrouped continuous count stations, i.e. the "Special Stations" group, were identified to be located on road sections with unusual or extreme patterns of monthly variations of traffic volume. The two ATR stations in the "Special Stations" group are located in a coal mining area and near a summer recreation area respectively (Table 1).

Road sections with unusual traffic volume variations require special treatment. That is, these road sections should be isolated from other road sections in estimating AADT volumes to increase accuracy levels. Among special traffic situations in the rural and suburban areas are as follows:

1. An isolated road leading to a resort area.
2. A certain area temporarily attracting unusual volumes of traffic during the hunting season.
3. Other situations causing extreme variations in traffic volumes or patterns.

To recognize these road sections, meetings with several planning staff were made. It was found that coal and summer recreation traffic have relatively significant effects on monthly volume variations compared with other special traffic patterns. These traffic patterns result from coal hauling truck traffic in mining areas and recreational

facilities within a few summer resorts, memorials, museums and the like. The problem is to determine how many resort area roads and coal mining area roads are involved in the two "Special Station" groups.

In the next two subsections, highways utilized by coal traffic and recreational traffic are discussed.

Coal Traffic Routes

Introduction. A project is now being developed under the Division of Planning to develop estimates of the state's highway needs related to coal hauling, the most critical need of the several categories of highway uses from 1976 to 1985 that are identified in the "needs report" (20). The report, "Highway Needs Analysis in Energy Production Regions of Indiana -- Coal" (21) served as a background document for the following coal haul routes study.

Coal Production. Although Indiana produces some petroleum and gas, present and future production is not expected to represent an increase from past production. The discovery rate of recent years does not offer great hope for a change. However, coal production is expected to increase substantially due to new demands for energy in the next few years and in the foreseeable future. Compared with the coal production, the production of other mines such as limestone, gravel, peat and clay is very low, and therefore does not cause great effects on the road network.

Coal production in Indiana ranks about eleventh in the U.S.A. The coal production regions of Indiana are concentrated in three districts. The southern area produces 60% of Indiana's coal; it is centered in Warrick, Spencer and Pike counties. The Middle Wabash area, centered

in Sullivan, Knox and Green counties, has a heavy concentration of steam power plants and produces 27% of the state's coal. The remainder (13%) comes from the northern end of the coal field including parts of Vermillion, Parke, Vigo and Clay counties. Figure D.1 shows the coal production areas in Indiana (22).

Indiana's annual production of 25 million short tons of coal is almost infinitesimal in contrast to its huge reserves, about 0.15 percent of total reserves. And, the reserve is in an advantageous geographical location with respect to industrial and power production needs. Therefore, the mining industry is expected to expand at least at a traditional rate of 3 to 4 percent annual increase.

Highway Needs of Coal Transportation. Highway transit of coal has increased greatly in recent years. The major producers with access to rail, shipped all their product by railroad, but the small operators, except those with rail access, shipped their product from the mine by truck. Due to the energy shortage, the increase in "small" coal operations and the increase in their production have been in existence for several years. As a result, the volume of coal traffic on the highways has increased.

The highway tonnage of coal transport will continue to increase in proportion to the total coal production in the state. It is estimated that the percentage of coal production hauled over the road will increase from 17% in 1976 to 25% in 1985. The increase in coal truck traffic is expected to reach 12.5 million tons per year by 1985. This estimate is supported by the facts shown from the location of several new fossil-fueled steam power plants in southeastern Indiana, the

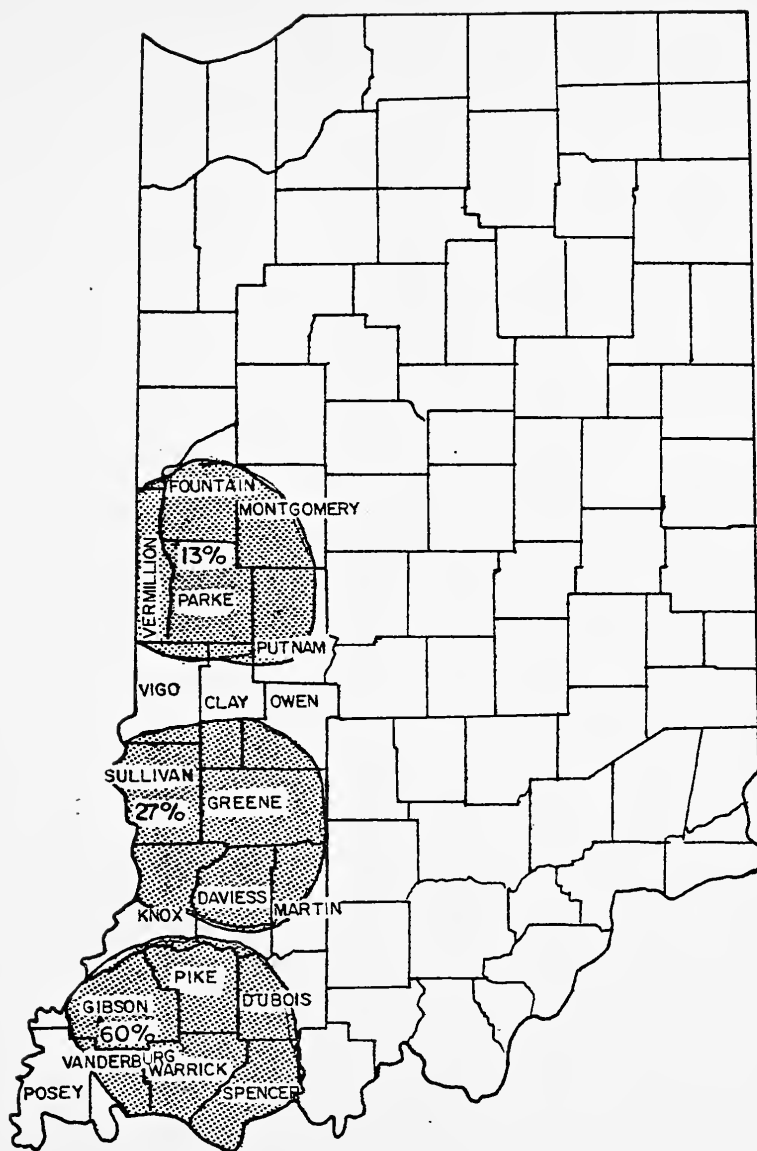


FIGURE D.I COAL PRODUCTION AREAS OF INDIANA

increased coal production, and the new port facilities on the Ohio River. 550,000 more truck loads of coal will be on the highways each year with an average trip length of 30 miles from mine to destination. Average loads per truck are 15 tons, so about 40,000 more trucks each year will travel from the mine to destination. The destination is most frequently a steam power plant in the area, but increased traffic is anticipated on the roads connecting the mining regions with river ports now being developed, such as Mt. Vernon, an Ohio River port in southern Indiana.

Road System Utilized by Coal Traffic. Most of the state highways in the coal production regions are used by coal trucks. The mileage of roads serving coal traffic is estimated at the following levels:

State primary system	650 miles
State secondary system	300 miles
County secondary (FA) system	70 miles
County secondaries (non FA)	50 miles

There is general agreement that the road system presently serving the coal mining regions requires no major new construction. The existing network including state highway system and county feeders serves all mining areas. The feeder routes over county roads serve to bring traffic to a hard surface state highway within two to three miles from the most operating mines in the state. Figure D.2 shows the state highway system part of the network presently used by the coal truck traffic (23).

From the above analysis and the indication of the unusual monthly volume variations at the continuous count station on a coal haul route, i.e. Station 74-A, it is found that coal traffic produces a pattern of variation, very much different from that observed in any of other highway categories, on the roads of the network. Given the scope of this research, only the state highway system, as shown in Figure D.2, is involved in the "Special Station" group - coal haul routes.

Recreational Traffic Routes

Introduction. There are few recreational areas in the state which attract large amounts of special traffic during holidays or weekends. The road sections leading to those recreational areas having significant seasonal traffic or having potential to attract seasonal traffic are recognized for the application of special group mean expansion factors.

Recreational Traffic Routes. There are few recreational traffic routes, which are considered to have unusual seasonal traffic volume variations by the Planning personnel.

Two such routes are S.R. 1 from Connorsville to Cedar Grove and S.R. 446 from Bloomington to the junction with U.S. 50. There are a series of state parks and recreation areas near these two routes.

Another route is S.R. 13 from the junction with U.S. 6 to the junction with U.S. 30. An ATR Station 281-A is located on this route, and unusual traffic situations have been indicated by this station. Tri-County State Fish and Wildlife Area is along this route.

A series of consecutive road sections on U.S. 36 from Indianapolis to Rockville and then on U.S. 41 to Turkey Run State Park are partly

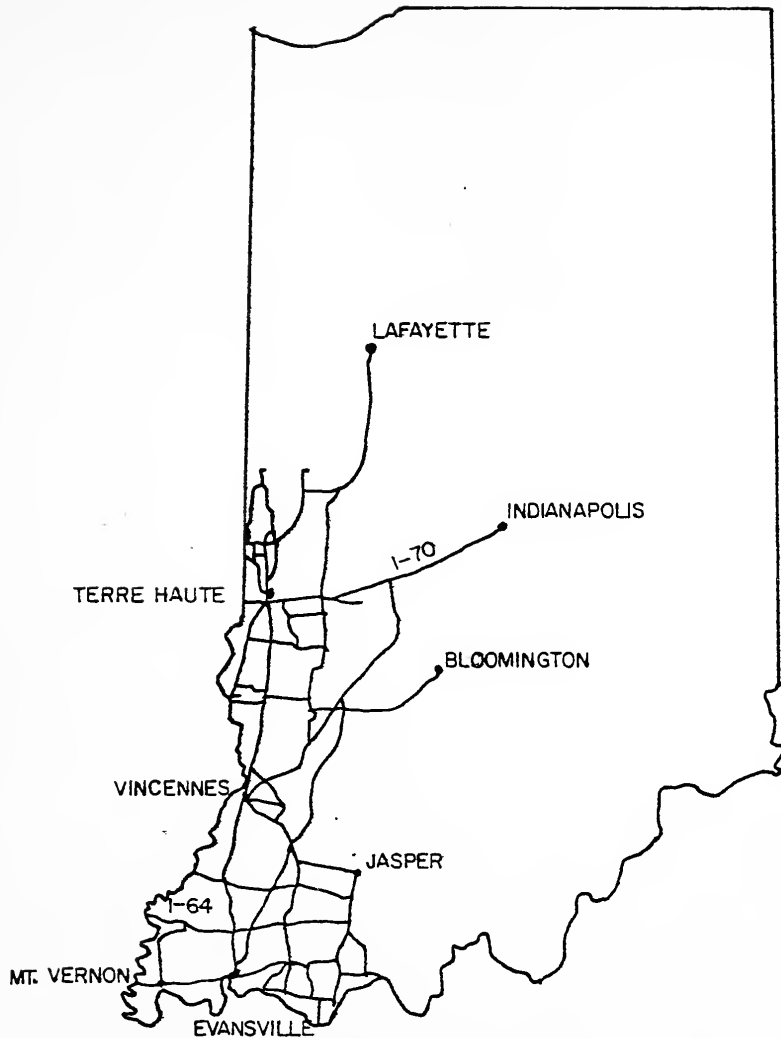


FIGURE D2 COAL TRAFFIC ON STATE HIGHWAY SYSTEM

affected by the recreational traffic. Raccoon Lake State Recreation Area is along U.S. 36. A growing amount of traffic occurs on the road sections leading to Turkey Run during vacation periods.

The above routes are shown in Figure D.3.

The Lincoln Heritage Trail is considered to have potential for traffic generation in the future. The Lincoln Heritage Trail is to standards which can be categorized as "complete marking", using Federal bicentennial funds allocated to the state. Years of experience with the Lincoln Heritage Trail have shown that marking will have little effect by itself on traffic generation. Recreational traffic will be generated due to a lot of historical memorials and parks along the Trail.

Figure D.4 indicates the Lincoln Heritage Main Trail and Alternate Trail in Indiana (24). This route map is duplicated directly from the Lincoln Heritage Trail official map. Part of the routes of the Trail duplicate some of the coal haul routes.

The recreational traffic routes in Figure D.3 are suggested to be involved in the existing "Special Station" group -- summer recreation area roads. There are no winter resort area roads in this state. If winter resort areas are developed, then their access roads will form another group with different seasonal traffic volume variations from those of the summer recreation roads group. As to the Lincoln Heritage Trail, its traffic volume characteristics are worth studying to determine whether there will be significant seasonal variations on the road sections of the Trail in the near future. If there are, the Trail road sections can be placed in a third group in the recreation area category if unique traffic volume variations are found on these road sections.

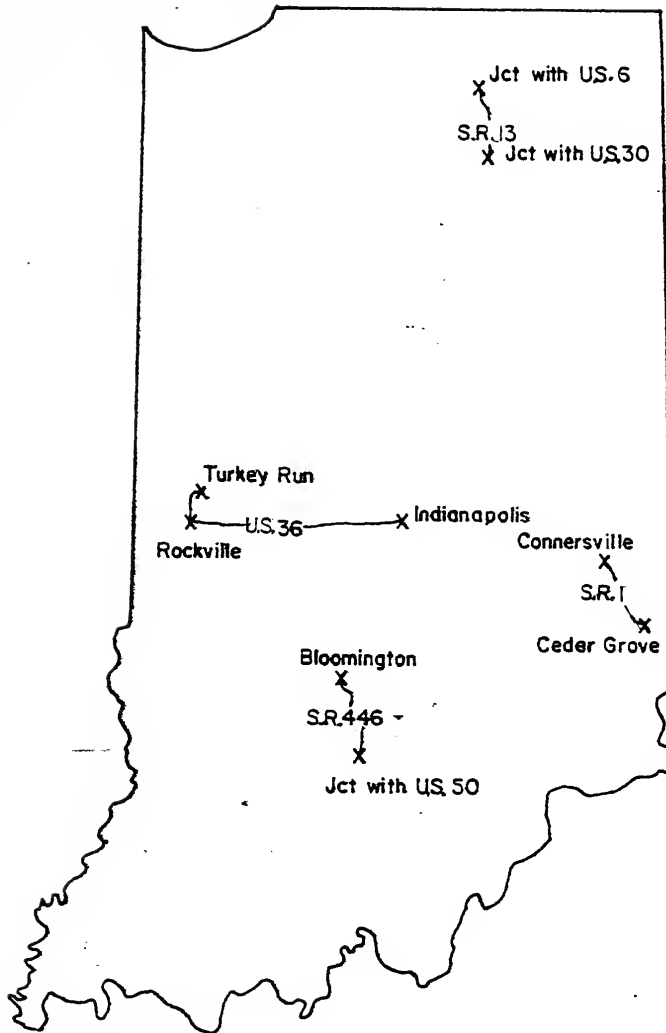


FIGURE D3 SUMMER RECREATION TRAFFIC
ON STATE HIGHWAY SYSTEM



FIGURE D.4 LINCOLN HERITAGE TRAIL ROUTE IN INDIANA

COVER DESIGN BY ALDO GIORGINI